Universitat de València
Facultat de Psicologia

ENHANCING SKILLS IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER THROUGH TECHNOLOGY-MEDIATED INTERVENTIONS

TESIS DOCTORAL

PROGRAMA DE DOCTORADO 3035
Investigación en Psicología

Presentada por:

Patricia Pérez Fuster

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Dra. Aglaia-Lila Kossyvaki

Valencia, marzo de 2017

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MEJORA DE HABILIDADES EN PERSONAS CON TRASTORNO DEL ESPECTRO AUTISTA CON INTERVENCIONES BASADAS EN TECNOLOGÍA

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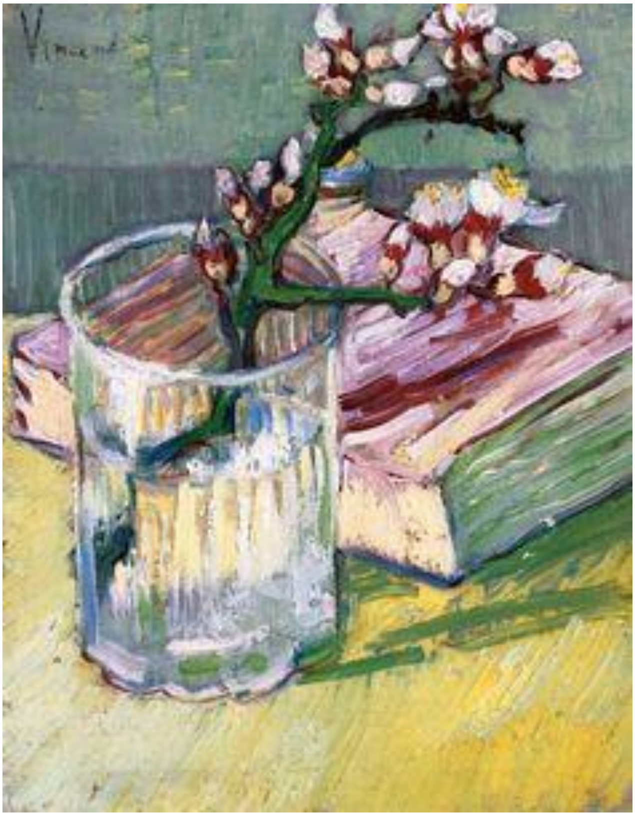
Als meus pares, Rafael i Mari Cruz,

per tot el que han fet i han deixat de fer per mi



Blossoming Almond Branch in a Glass with a Book
by Vincent van Gogh (1888)

“Cóm seria la vida si no tinguérem el valor d’intentar alguna cosa nova?”

“¿Qué sería de la vida si no tuviéramos el valor de intentar algo nuevo?”

“What would life be if we had no courage to attempt anything?”

— Vincent van Gogh

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AGRAÏMENTS / AGRADECIMIENTOS / ACKNOWLEDGEMENTS

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RESUMEN

Introducción

Marco teórico

Trastorno del Espectro Autista

El Trastorno del Espectro Autista (TEA), tal y como se define en el último Manual Diagnóstico y Estadístico de los Trastornos Mentales (DSM-5; APA, 2013), se caracteriza por la presencia de dificultades persistentes en la comunicación social y en la interacción social en diversos contextos (e.g., dificultades para compartir juegos imaginativos), y patrones restrictivos y repetitivos de comportamiento, intereses o actividades (e.g., movimientos estereotipados). El diagnóstico de TEA puede ir acompañado de dificultades en lenguaje y discapacidad intelectual. Estos síntomas están presentes en las primeras fases del período del desarrollo indicando que el niño que es posteriormente diagnosticado con TEA tiene un desarrollo temprano diferente a aquél del niño con desarrollo típico (DT).

Desarrollo en el primer año de vida

Según Rivière (1990), si los niños con TEA tienen dificultades en diferentes áreas del desarrollo como la interacción social, el lenguaje verbal, el sistema emocional, habilidades simbólicas y juego imaginativo, es porque dichas funciones están interconectadas en el DT como un *racimo funcional*. El bebé, desde que nace, es un *animal social* que muestra un mayor interés ante estímulos sociales ofrecidos por personas, comportamientos preimitativos y patrones de sincronía interactiva (Condon y Sander, 1974). En los tres primeros meses de vida, el bebé desarrolla la habilidad de compartir el mundo interno de otras personas a través de su sistema emocional y la empatía, mostrando gestos faciales y otras expresiones emocionales, sintiendo a su vez la emoción que dichos gestos representan. A esta habilidad se le ha denominado *intersubjetividad primaria* (Trevarthen, 1980).

Hacia los seis meses, los bebés desarrollan habilidades que les ayudan a beneficiarse de las contingencias sociales y a anticipar situaciones a partir del recuerdo y reconocimiento de las figuras de apego. Hacia los ocho meses, el bebé desarrolla *conductas protoimperativas* dirigidas a pedir alguna cosa y *conductas protodeclarativas* cuyo fin es el de compartir la experiencia y el interés por un objeto o situación. Hacia los doce meses de edad, el bebé muestra constantes conductas protoimperativas y protodeclarativas. Sin embargo, los niños con TEA presentan dificultades en la mayoría, si no en todas, las habilidades anteriores. Particularmente, la ausencia de conductas protodeclarativas es la característica más evidente del niño que es posteriormente diagnosticado con TEA. Esta dificultad está asociada al hecho de que el infante no ha alcanzado el siguiente nivel de intersubjetividad (Tomasello, 1995), según el cual este debe ser capaz de percibir a los demás como personas que piensan y sienten igual que él y con quien puede compartir sus pensamientos e intereses (Hobson, 1993; Baron-Cohen, Leslie y Frith, 1985). Siguiendo el concepto de racimo funcional, cuando la evolución de las habilidades anteriores es limitada, el desarrollo de los símbolos y la aparición del lenguaje también se ven afectados. En consecuencia, el niño con TEA está en riesgo de crecer sin un sistema de comunicación en un mundo altamente impredecible, quedando expuesto a una falta de significado constante y, por tanto, a una limitada capacidad para ejercer control sobre él.

Atención conjunta

Las conductas protodeclarativas están directamente relacionadas con la habilidad de atención conjunta (AC) que puede definirse como la capacidad de una persona para compartir con otra el foco de atención hacia un determinado objeto o evento mediante el uso de gestos como seguir la mirada o señalar. Tradicionalmente, se han diferenciado dos grandes grupos de habilidades de AC: iniciación de AC (IAC), que incluye habilidades como el contacto visual o el cambio del punto de la mirada para dirigir la atención de un compañero social hacia un foco de interés, y respuesta de AC (RAC), que incluye habilidades como seguir la mirada o señalar en respuesta a una interacción iniciada por un compañero social. El niño con TEA que todavía está en la fase preverbal del desarrollo presenta dificultades en IAC y, sobre todo en RAC, en comparación con los niños con DT. Conforme el niño con TEA avanza hacia fases más tardías del desarrollo y adquiere lenguaje, las diferencias en RAC en comparación a los niños con DT se reducen. Sin embargo, las diferencias en IAC se mantienen significativas durante más tiempo, presentando el niño con TEA un número mucho menor de conductas de IAC (Mundy, Sigman, Ungerer y Sherman, 1986). Esto indica que las habilidades de RAC son críticas para muchos aspectos del desarrollo infantil, entre ellos la adquisición de lenguaje (Charman, 2003), mientras que las habilidades de IAC parecen estar más asociadas a diferencias crónicas entre personas con TEA y personas con DT (Gangi, Ibañez y Messinger, 2014).

Intervenciones en AC

Métodos y técnicas de instrucción tradicionales con un enfoque conductual como el análisis de conducta aplicado (ABA) y la enseñanza mediante ensayos discretos (DTT; Lovaas, Berberich, Perloff y Schaeffer, 1966) o el ensayo de respuesta pivote (PRT; Koegel y Koegel, 1988), así como métodos con un enfoque más interaccionista e inclusivo como el *Modelo Denver de atención temprana para niños pequeños con autismo* (ESDM; Rogers y Dawson, 2010), han sido efectivos para la mejora de habilidades de AC (e.g., Martins y Harris, 2006; Rogers et al., 2006; Whalen y Schreibman, 2003). Métodos específicamente dirigidos a la mejora de habilidades de AC como JASPER, de sus siglas en inglés *Joint Attention, Symbolic Play Engagement and Regulation* (Kasari, Freeman y Paparella, 2000), también han resultado significativamente eficaces (e.g., Kasari, Freeman y Paparella, 2006).

Tecnologías de la información y la comunicación

Por otro lado, el uso de tecnologías de la información y la comunicación (TIC) como ordenadores personales (PCs), móviles inteligentes de última generación o tabletas es una práctica que va en aumento en las intervenciones con personas con TEA debido al gran interés que estos dispositivos tecnológicos despiertan en la mayoría de ellas. El hecho de que las TIC ofrecen principalmente información visual, pueden personalizarse de acuerdo con necesidades de comunicación, dificultades sensoriales, preferencias e intereses, y ofrecen entornos altamente predecibles, son algunas de sus ventajas más prominentes. Desde la década de los setenta en que se publicaron los primeros estudios que exploraron el impacto del uso de las TIC en personas con TEA (Colby, 1973; Colby y Smith, 1971), el número de publicaciones sobre este tema ha registrado un continuo ascenso, y ha sido la entrada del s. XXI, acompañada de múltiples hallazgos científicos e importantes avances tecnológicos, la que ha supuesto un crecimiento exponencial en el número de tales publicaciones (Kientz, Goodwin, Hayes y Abowd, 2014).

Evidencias basadas en la práctica de TIC para TEA

Numerosas revisiones narrativas (e.g., Goodwin, 2008) y sistemáticas (e.g., Wass y Porayska-Pomsta), algunas de las cuales incluyen meta-análisis (e.j., Grynszpan, Weiss, Pérez-Díaz y Gal, 2014), se han llevado a cabo con el fin de sintetizar grupos de estudios en los que se han utilizado TIC y evaluar el impacto conjunto que estas han tenido sobre las personas con TEA. Estas revisiones indican que el uso de TIC puede ser efectivo, pero detectan limitaciones metodológicas importantes en los estudios empíricos tales como el uso de muestras de participantes pequeñas y la ausencia de estudios longitudinales (Fletcher-Watson, 2014). Estas limitaciones están relacionadas, entre otros factores, con el ciclo corto de vida que tienen las TIC (Herrera, 2015), pues para realizar un estudio metodológicamente riguroso se precisa de mucho más tiempo del que *viven* algunas TIC debido a su rápida evolución y fácil extinción. Dichas limitaciones dificultan el establecimiento de evidencias basadas en la práctica (EBP) en el campo de las TIC para TEA, complicando que las TIC lleguen a considerarse una herramienta de intervención ciertamente efectiva.

Estructura de la presente tesis doctoral

Esta tesis está formada por tres estudios que están relacionados entre sí. A continuación, se detalla el objetivo, método y principales resultados de cada uno de ellos.

Estudio 1

Objetivo

El objetivo de este estudio consistió en llevar a cabo una revisión sistemática de la literatura para describir las tendencias actuales de intervenciones basadas en el uso de TIC para personas con TEA.

Método

Para ello, se realizó una búsqueda sistemática en cuatro bases de datos electrónicas: PsycINFO, Education Resources Information Center (ERIC), PubMed y Wed of Science. Se utilizaron palabras clave relacionas con TEA (e.g., autism) y TIC (e.g., computer) para localizar artículos escritos en inglés y publicados en revistas revisadas por pares durante el periodo 2000-2015 (el detalle de términos y combinaciones puede consultarse en el Apéndice A). Asimismo, se realizaron búsquedas manuales en las listas de referencias de los artículos identificados.

Se establecieron criterios de inclusión y de exclusión. Cada estudio tenía que evaluar la efectividad de una intervención de una duración no inferior a dos sesiones, basada en el uso de al menos una TIC, con al menos una persona con TEA, y dirigida a la mejora de una habilidad relacionada con síntomas de TEA, un área curricular, u otro aspecto relacionado con el bienestar de la persona. Estudios de revisión, evaluación o de viabilidad de TIC fueron excluidos del análisis.

Para la selección de estudios y extracción de información se llevó a cabo un minucioso procedimiento basado en el acuerdo entre jueces para el cual la autora de esta tesis contó con la ayuda de dos compañeras de investigación. Se partió de una lista inicial sin duplicados de más de 3,000 artículos cuyos títulos y resúmenes fueron examinados. Tras eliminar, en primer lugar, aquellos que no estaban relacionados con el tema de investigación y, en segundo lugar, aquellos que, estando relacionados, no cumplían los criterios de inclusión, 171 fue el número total de artículos obtenidos en la búsqueda electrónica. Además, se incluyeron siete estudios localizados manualmente.

Estos 178 artículos fueron examinados para extraer información sobre: (a) las características de los participantes (número, género, edad y diagnóstico); (b) la TIC utilizada como variable independiente; (c) la habilidad medida como variable dependiente; (d) el diseño de investigación aplicado; (e) el lugar donde se implementó la intervención; (f) el país en el cual se realizó; (g) el año en que se publicó el artículo; (h) la revista en la cual se publicó el artículo.

Tanto en la selección de los estudios como en el procedimiento de extracción de información, se alcanzó un 100% de acuerdo entre jueces. Se llevaron a cabo análisis univariados y bivariados sobre los datos obtenidos para las variables mencionadas anteriormente, utilizando el programa IBM SPSS Statistics 22.0.

Resultados

El número de participantes incluidos en cada estudio fue desde uno hasta 121. Estos fueron principalmente varones en edad escolar de primaria y secundaria (5-17 años). Se detectó una escasez de estudios con mujeres y con personas de edad adulta (+18 años). Algunos estudios no reportaron información sobre el género y la edad de los participantes. En cuanto al diagnóstico, se encontró una variedad muy amplia de etiquetas diagnósticas, no siempre acompañadas de las herramientas de evaluación correspondientes, que impidió elaborar un resultado general.

En cuanto a las TIC, se obtuvo información del aparato o *hardware* (HW; e.g., PC, tableta, etc.), la naturaleza del programa utilizado o *software* (SW;

genérico, para necesidades especiales o creado para la investigación), y el método concreto que se empleó para enseñar (MoD; secuencia interactiva, desencadenamiento, etc.). Los PCs seguidos de las tabletas, los teléfonos inteligentes y los robots son los HW más utilizados en las intervenciones con personas con TEA. En general, el SW genérico fue más utilizado, sobre todo con teléfonos inteligentes. Sin embargo, las tabletas fueron muy utilizadas con SW para necesidades especiales y los robots principalmente con SW creado para la investigación. Secuencia interactiva y desencadenamiento fueron los métodos más empleados en las intervenciones, sobre todo aquellas basadas en el uso de PCs, tabletas y teléfonos inteligentes. Agente interactivo fue el método escogido por la mayoría de estudios basados en el uso de robots.

Las habilidades se dividieron en tres grupos: comunicación e interacción social, académicas y de la vida cotidiana. La mayoría de los estudios se dirigieron a la mejora de habilidades de comunicación e interacción social, sobre todo aquellos enfocados en niños en edad temprana y primaria (2-11 años). Los estudios enfocados en participantes de edad secundaria (12-17 años) se dirigieron a la mejora de habilidades académicas y aquellos enfocados en participantes adultos (18+ años) se dirigieron principalmente a la mejora de habilidades de la vida cotidiana.

La mayoría de los estudios (principalmente aquellos que contaron con menos de 10 participantes) empleó diseños de caso único, sobre todo diseños de línea base múltiple y de prueba múltiple. De aquellos estudios que emplearon diseños de grupo (principalmente aquellos que contaron con 10 participantes o más) la mitad lo hicieron sin incluir un grupo control o de comparación. Un número muy pequeño de estudios aplicaron ensayos controlados y aleatorizados, habiendo sido estos publicados en los últimos tres años recogidos en la revisión.

Entornos naturales como la escuela fueron los lugares elegidos por la mayoría de los estudios para llevar a cabo las intervenciones basadas en el uso de TIC, sobre todo aquellas dirigidas a participantes en edad primaria y secundaria (5-

17 años) y enfocadas en la mejora de habilidades de comunicación e interacción social y académicas. Sin embargo, aquellos estudios realizados en centros vocacionales o entornos laborales se dirigieron a personas de edad adulta (18+ años) y se enfocaron en la mejora de habilidades de la vida cotidiana.

Los estudios se realizaron en 22 países diferentes. Estados Unidos, seguido de Reino Unido, fueron los países en los que se llevaron a cabo un mayor número de intervenciones con TICs en personas con TEA. El número de publicaciones fue incrementándose gradualmente desde 2010, hasta alcanzar un crecimiento de un 214% en 2010-2015 en comparación con 2000-2009. En el último año el crecimiento fue más significativo, habiéndose detectado un 38% más de publicaciones en 2015 que en 2014. Los artículos se publicaron en un total de 75 revistas, 45 de las cuales están actualmente incluidas en el *Journal Citation Reports®* de Thomson Reuters (2016). Revistas especializadas en TEA y necesidades especiales publicaron la mayoría de los estudios, siendo *Journal of Autism and Developmental Disorders* la revista que publicó un mayor número de ellos.

Estudio 2

Objetivo

El objetivo de este estudio fue doble. En primer lugar, se llevó a cabo una revisión sistemática de la literatura para describir las intervenciones basadas en el uso de TIC que se implementaron para la mejora de habilidades de AC en personas con TEA. Y, en segundo lugar, se analizó la calidad metodológica y se determinó el nivel de evidencia alcanzado por los estudios que fueron incluidos en la revisión sistemática.

Método

Para la revisión sistemática, se aprovechó la búsqueda realizada en el Estudio 1, pues fue lo suficientemente amplia como para identificar los estudios que se incluirían en esta nueva revisión. Asimismo, los criterios de inclusión y de exclusión establecidos para el Estudio 1, se aplicaron en este estudio, por lo que el número de artículos del cual se partió fue de 178. Sin embargo, puesto que el objetivo de esta nueva revisión fue más preciso, se añadió un nuevo criterio de inclusión: cada estudio tenía que enfocarse específicamente en la mejora de, al menos, una habilidad de AC (e.g., seguir la mirada o señalar). Tras aplicar este criterio adicional, se incluyeron en la revisión un total de cinco estudios. Las variables a analizar fueron las mismas que en el Estudio 1, especificando las habilidades de AC enseñadas en cada estudio de intervención. Puesto que el número de artículos fue manejable, en comparación al conjunto incluido en el Estudio 1, se llevó a cabo una nueva revisión pormenorizada de cada uno de los estudios para extraer información más detallada para cada una de las variables.

Para analizar la calidad metodológica y determinar el nivel de evidencia alcanzado por los cinco estudios incluidos en la revisión sistemática, se aplicó el método de evaluación de Reichow, Volkmar y Ciccetti (2008), que consiste en un conjunto de herramientas que han sido diseñadas para medir el rigor y la fuerza de un grupo de estudios y determinar su nivel de EBP (ver Apéndice D). Este método estandarizado fue elegido entre todos los que se encuentran disponibles en la literatura por dos razones principalmente: ha sido desarrollado para evaluar la evidencia empírica de intervenciones para personas con TEA y permite evaluar un conjunto de estudios que presentan una combinación de diferentes diseños de investigación (diseños de caso único y diseños de grupo).

Resultados

Los cinco artículos incluidos en la revisión sistemática fueron los de Cheng y Huang (2012), Costa, Lehman, Dautenhahn, Robins y Soares (2015), Goodrich et al. (2012), Tapus et al. (2012), y Warren et al. (2015). Un total de 23 participantes varones de entre 2 y 12 años fueron incluidos en los estudios. En cuanto al diagnóstico de los participantes, al igual que ocurría en el Estudio 1, se detectó el uso de una variedad de etiquetas diagnósticas (TEA, autismo, autismo moderado, autismo severo y trastorno generalizado del desarrollo) y de diferentes herramientas para el diagnóstico (i.e., Autism Diagnostic Observation Schedule [ADOS] y Childhood Autism Rating Scale [CARS]), que no fueron reportadas en todos los estudios.

En cuanto a las TIC, cuatro de los estudios utilizaron robots y un estudio utilizó realidad virtual (RV). Más concretamente, Tapus et al. (2015) utilizaron el robot Nao con un sensor Kinect para que este pudiera seguir los movimientos del participante. Warren et al. (2015) también utilizaron el robot Nao, pero con un sistema de seguimiento de ojos para registrar la mirada de los participantes. Goodrich et al. (2012) desarrollaron el robot Troy y lo usaron en combinación con un mando Wii para dirigir al robot en función de las acciones del participante. Costa et al. (2015) utilizaron el robot KASPAR con un teclado con el que controlaron las respuestas del robot a partir de las acciones del participante. Finalmente, Cheng y Huang (2012) desarrollaron un programa de RV denominado JASL, de sus siglas en inglés *Joint Attention Skills Learning*, para el uso del cual necesitaron un ordenador y dos proyectores. También añadieron al sistema un teclado y *data glove*, que son unos guantes utilizados para interaccionar, mediante motricidad fina, con entornos virtuales y de robótica. Los cinco estudios utilizaron SW que fue especialmente diseñado para sus investigaciones. En todos los estudios en los que se usó un robot, el método utilizado para implementar la intervención fue el de agente interactivo. El estudio que usó RV incluyó agente interactivo y también simulación.

En cuanto a las habilidades de AC, los estudios revisados se enfocaron en un rango amplio de diferentes habilidades de IAC y RAC. Más concretamente, Cheng y Huang (2012) usaron el programa JASL para la mejora de las habilidades de IAC de mostrar y compartir, y de las habilidades de RAC de señalar y mostrar. Costa et al. (2015) utilizaron al robot KASPAR para la mejora de las habilidades de IAC de tocar al robot y señalar, y de las habilidades de RAC de seguir al robot con la mirada, seguir sus ojos, tocarle, señalarle y mover la cabeza. Goodrich et al. (2012) utilizaron Troy para mejorar las habilidades de IAC de utilizar la mirada, señalar y usar otros gestos para dirigir la atención del otro, y las habilidades de RAC de seguir al robot con la mirada, girar la cabeza y señalar. Tapus et al. (2012) utilizaron a Nao para mejorar la habilidad de IAC de iniciar acciones de motricidad gruesa mientras se mira al compañero de interacción, y la habilidad de RAC de seguir la mirada del compañero de interacción. Finalmente, Warren et al (2015) utilizaron a Nao para mejorar la habilidad de RAC de girarse para mirar el objeto de atención compartida.

Goodrich et al. (2012), Tapus et al. (2012), y Cheng y Huang (2012) aplicaron diseños de caso único (AB, ABAC y diseño de prueba múltiple, respectivamente), mientras que Warren et al. (2015) y Costa et al. (2015) aplicaron diseños de grupo. Tres de los estudios fueron realizados en laboratorios (Cheng y Huang, 2012; Tapus et al., 2012; Warren et al., 2015), un estudio en una clínica de intervención (Goodrich et al., 2012) y un estudio en un colegio de primaria para niños con necesidades educativas especiales (Costa et al., 2015). Los estudios se llevaron a cabo en cuatro países distintos: Estados Unidos (Goodrich et al., 2012; Warren et al., 2015), Reino Unido (Costa et al., 2015), Rumanía (Tapus et al., 2012) y Taiwán (Cheng y Huang, 2012). Aunque la revisión incluyó artículos publicados desde 2000, los primeros estudios dirigidos a la mejora de AC mediante el uso de TIC no aparecieron hasta 2012. Esto indica que los cinco estudios fueron publicados en los últimos cinco años. Cada estudio se publicó en una revista distinta, estando algunas más especializadas en TEA y otras más especializadas en TIC, y todas ellas incluidas en el *Journal Citation Reports®* de Thomson Reuters (2016).

Los cinco estudios obtuvieron valores bajos en rigor metodológico, principalmente debido a la falta de una mayor descripción de las características de los participantes, la ausencia de evaluación del mantenimiento y generalización de las habilidades enseñadas, y la participación de personas responsables de la intervención que desconocían a los participantes y viceversa. Ninguno de los dos estudios de grupo incluyó un grupo de control o de comparación ni tampoco indicó el tamaño del efecto de las intervenciones. Solamente uno de los tres estudios que emplearon diseño de caso único informó sobre la línea base, el análisis visual de los datos y el control experimental. Por tanto, aunque las intervenciones basadas en el uso de TIC fueron efectivas en la mejora de las habilidades de AC en 21 de los 23 participantes incluidos en los estudios, estas no se establecieron como EBP.

Estudio 3

Objetivo

El objetivo de este estudio consistió en explorar el impacto de una intervención basada en el uso de una tecnología de realidad aumentada denominada *Pictogram Room* sobre la mejora de las habilidades de RAC de seguir la mirada y señalar en niños con TEA. Con el fin de conseguir el mayor rigor metodológico, se tuvieron en cuenta los resultados obtenidos en el Estudio 1 y en el Estudio 2, así como los criterios de calidad especificados en el método de evaluación de Reichow et al. (2008).

Método

Siete niños de entre tres y ocho años, sin dificultades visuales y diagnóstico de TEA con déficit intelectual y deterioro del lenguaje (DSM-5) participaron en este estudio. También dos de los participantes presentaban diagnóstico de Trastorno por Déficit de Atención e Hiperactividad (TDAH). El estudio se llevó a cabo en el centro escolar de infantil y primaria en el que estos alumnos estudiaban y que está situado en la localidad de Manises (Valencia, España). Los siete estaban escolarizados en una modalidad denominada aula de comunicación y lenguaje (aula CyL), destinada exclusivamente a la enseñanza de alumnos con diagnóstico de TEA o trastorno del lenguaje. Todos los alumnos utilizaban el sistema de comunicación PECS (de sus siglas en inglés *Picture Exchange Communication System*) excepto uno que presentaba lenguaje expresivo en forma de frases cortas funcionales. El aula CyL seguía metodología de enseñanza TEACCH (de sus siglas en inglés *Treatment and Education of Autistic and related Communication*

Handicapped Children) y, siguiendo los principios de inclusión, los siete alumnos atendían algunas materias en sus clases de referencia y compartían descansos con compañeros de DT y con otras necesidades educativas especiales. La maestra de pedagogía terapéutica y la maestra de audición y lenguaje del aula CyL también participaron en el estudio.

El lugar donde se llevaron a cabo todas las sesiones de evaluación y de intervención se denominaba aula de audiovisuales. En ella se montó el sistema Pictogram Room: un conjunto de videojuegos para Kinect especialmente diseñados para mejorar una amplia gama de habilidades, incluyendo AC, en personas con TEA. Para ello se necesitó un PC con Windows 7, una Kinect, un proyector y una pantalla grande. Además, se contó con un equipo de tres cámaras y micrófono para grabar las sesiones.

Para contrastar el diagnóstico de TEA y la capacidad intelectual de los participantes se utilizó el Cuestionario de Comunicación Social (SCQ; Rutter, Bailey y Lord, 2003) y la escala manipulativa internacional de Leiter (Leiter-R; Roid y Miller, 1997) respectivamente. Para evaluar las habilidades de RAC se empleó la Escala de Observación para el Diagnóstico del Autismo (ADOS-2; Lord et al., 2012) y las Escalas de Comunicación Social Temprana (ESCS; Mundy et al., 2003). Finalmente, para evaluar las habilidades concretas de RAC de seguir con la mirada y señalar se utilizaron tres materiales no estandarizados: un disfraz con forma de muñeco, unas tortugas de plástico con un sistema mecánico incorporado para hacer que anden y unos pósters plastificados con dibujos animados.

Los siete alumnos fueron asignados aleatoriamente a tres grupos, uno de tres alumnos, y dos grupos de dos alumnos cada uno. Se aplicó un diseño de caso único con línea de base múltiple a través de los tres grupos. La duración total del estudio fue de 12 semanas. Los tres grupos recibieron una sesión de evaluación previa, seis sesiones de intervención con Pictogram Room (tres sesiones por semana), y dos sesiones de evaluación un mes después de la intervención. Los grupos únicamente se diferenciaron en la duración de sus líneas base (sesiones entre la primera sesión de evaluación y las sesiones de intervención): tres sesiones para el primer grupo, seis para el segundo, y nueve para el tercero. En las sesiones de evaluación pre y post se aplicaron el ítem de RAC del ADOS-2, el ESCS y una prueba no estandarizada en la que la autora de esta tesis colocaba en 10 ocasiones dos pósters y en 10 ocasiones dos tortugas, uno a cada lado a la altura de sus ojos y miraba hacia uno de ellos. El participante, sentado en frente, tenía que seguir su mirada y señalar o coger el objeto mirado. Acertase o no, podía coger el objeto e interaccionar con él. La puntuación iba de 0 (ningún acierto) a 10 (10 aciertos) con los pósters y también de 0 a 10 con las tortugas. En las sesiones de línea base se evaluaban las habilidades de los participantes de mismo modo, pero utilizando el disfraz de muñeco, siendo los ojos de este los que miraban al objeto. Durante las sesiones de intervención, se utilizó un juego de Pictogram Room denominado *seguir con la mirada* en el que el participante se veía reflejado en la pantalla debido a la realidad aumentada y, con la ayuda y compañía de una de sus maestras, tenía que seguir los ojos de un muñeco virtual y tocar una ventana (de entre dos o cuatro más) a la que este muñeco miraba. Si acertaba, la ventana se abría y mostraba su vídeo favorito. Si no acertaba, las ventanas desaparecían y se le ofrecía un nuevo intento. El participante jugaba durante 15 minutos y a continuación se le evaluaba con el muñeco tal y como se ha descrito para las sesiones de línea base.

En el estudio se llevaron a cabo numerosos controles, entre ellos, la personalización de Pictogram Room de acuerdo con las necesidades sensoriales, preferencias e intereses de los participantes, la inclusión de su sistema de comunicación PECS, la anticipación de las actividades relacionas con el estudio y la transición entre el aula CyL y el aula de audiovisuales antes y después de cada sesión.

Para la fiabilidad de las medidas, que fueron obtenidas mediante vídeo análisis, el acuerdo entre jueces y el coeficiente de Kappa fueron calculados. La efectividad de la intervención con Pictogram Room fue analizada mediante el cálculo del coeficiente *Phi* de Pearson y el *porcentaje de todos los datos no solapados* (PAND; Parker, Hagan-Burke y Vannest, 2007) que se obtuvieron en la evaluación con el disfraz de muñeco en cada sesión de línea base y de intervención. La generalización y mantenimiento de las habilidades aprendidas fueron analizadas mediante la comparación de las medidas obtenidas antes y después de la intervención.

Resultados

Los siete niños participaron durante todo el estudio. Sin embargo, los resultados de uno de ellos (uno de los dos niños que presentaban diagnóstico dual de TEA y TDAH) no se incluyeron en los análisis, pues la mayoría de sesiones de evaluación e intervención se vieron interrumpidas por la presencia de importantes déficits de atención, hiperactividad y dificultades de conducta. De este modo, los tres grupos incluyeron dos participantes cada uno.

Con un acuerdo entre jueces y coeficiente Kappa igual a 1, indicando máxima fiabilidad, la intervención resultó efectiva para la mejora de las habilidades de RAC de seguir la mirada y señalar de los otros seis participantes. Se observó que conforme avanzaba la intervención, los participantes seguían mejor la mirada del disfraz de muñeco y señalaban el objeto (póster o tortuga) correcto. No se observó, sin embargo, ninguna mejora en las sesiones de línea base. El momento en que se introdujo la intervención con Pictogram Room en cada grupo fue cuando las puntuaciones de los participantes mostraron un cambio positivo debido al aumento del porcentaje de aciertos. Cinco de los seis participantes mostraron mejoras desde la primera sesión de intervención, no presentando ningún punto de solapamiento en las puntuaciones obtenidas en la línea base y la intervención. Los cinco consiguieron en algún momento de la intervención responder correctamente a los 10 ensayos con los pósters o a los 10 ensayos con las tortugas, e incluso ambos. Sin embargo, uno de los participantes (el segundo de los niños que presentaba diagnóstico dual de TEA y TDAH) no mostró mejoras hasta la cuarta sesión de intervención, presentando algunos puntos de solapamiento entre la línea base y la intervención. Además, no consiguió responder correctamente a todos los ensayos ofrecidos con los pósters o las tortugas en ninguna de las sesiones. En las sesiones de seguimiento, todos los participantes mantuvieron la habilidad de RAC de seguir la mirada del disfraz de muñeco y señalar al objeto de atención compartida (póster o tortuga) que consiguieron hacia el final de la intervención con Pictogram Room.

Con todo ello, los datos mostraron un PAND del 98% para los ensayos con pósters y del 96% para los ensayos con tortugas, indicando que la intervención fue altamente efectiva (PAND > 90%) para mejorar las habilidades de RAC de seguir la mirada y señalar un objeto de atención compartida de seis niños con TEA y diferentes habilidades cognitivas y de lenguaje. Además, se obtuvo un coeficiente *Phi* de Pearson de 0.96 ($p < .01$) para los ensayos con pósters y un coeficiente *Phi* de Pearson de 0.92 ($p < .01$) para los ensayos con tortugas, indicando una asociación positiva fuerte (*Phi* > .70) entre la intervención y los resultados obtenidos. Además, los datos recogidos antes y después de la intervención mostraron que la mejora observada en las habilidades de RAC con el disfraz de muñeco se generalizaron a una mirada real, así como a otras habilidades de RAC, como señalar a un objeto situado detrás del niño.

Este estudio sería considerado metodológicamente riguroso y fuerte según el método de evaluación de Reichow et al. (2008) siendo elegible para estudios de replicación y revisiones meta-analíticas.

Conclusión

El Estudio 1 describe ampliamente las características de los estudios de intervención basados en el uso de TIC con personas con TEA, y ofrece una extensa lista de investigaciones que puede ser muy útil en futuros estudios empíricos y de revisión. Asimismo, identifica limitaciones metodológicas en los estudios que están relacionadas sobre todo con la falta de descripción de los participantes y el uso de diseños de investigación poco rigurosos, y que sirven de base para la elaboración de buenas recomendaciones para futuras investigaciones.

El Estudio 2 muestra cómo intervenciones basadas en el uso de TIC, tales como robots y RV, pueden ser efectivas en la mejora de habilidades de IAC y RAC en niños con TEA. Mediante el uso de potentes indicadores de calidad, esta revisión muestra también las limitaciones metodológicas que pueden presentar los estudios de este tipo, la mayoría de las cuales ya habían sido identificadas en el Estudio 1, y propone alternativas de cara a fortalecer futuros estudios empíricos para que éstos puedan ser adecuadamente replicados e incluidos en estudios meta-analíticos.

El Estudio 3 es una investigación empírica rigurosa que ha demostrado que una intervención basada en el uso de un sistema de realidad aumentada (Pictogram Room) puede mejorar las habilidades de RAC de seguir la mirada y señalar en un grupo de niños con TEA. La eficacia de la investigación puede ser atribuida en parte al beneficio que ha supuesto el conocimiento de las limitaciones halladas en el Estudio 1 y el Estudio 2, y al hecho de haber tenido como marco de referencia unos criterios de calidad durante el diseño e implementación del estudio.

A continuación, se detallan algunas de las principales implicaciones tanto a nivel de investigación como a nivel práctico que se derivan de los tres estudios de forma conjunta.

Debido al constante crecimiento de los estudios de intervenciones basadas en el uso de TIC en personas con TEA, deben continuar realizándose estudios de revisión narrativa y sistemática y, cuando sea posible, que estos últimos incluyan meta-análisis que informen de una forma cuantitativa acerca del impacto de las intervenciones. Para facilitar la labor de investigadores que deseen realizar estudios de replicación o de revisión, futuros estudios empíricos deben aportar toda la información que ha sido recogida en las revisiones incluidas en esta tesis, describiendo especialmente las características de los participantes (e.g., edad y género), tanto de las personas con TEA como de los responsables de las intervenciones.

Cuando la muestra de participantes sea pequeña, se recomienda la aplicación de diseños de caso único rigurosos como, por ejemplo, diseños de línea base múltiple, dejando siempre que sea posible la aplicación de diseños de grupo para cuando se tenga un mayor número de participantes y se pueda incluir un grupo control o grupo de comparación, con asignación aleatoria a ser posible (ensayos controlados y aleatorizados). Y, siempre que sea posible, se debe informar acerca del tamaño del efecto de cada intervención, pues es un dato clave para poder incluir ese estudio en un meta-análisis.

En general, más mujeres y personas adultas con TEA deben participar en estudios de intervenciones basadas en el uso de TIC, pues podrían beneficiarse al igual que lo hacen los varones y personas más jóvenes y niños. Con el fin de fortalecer la validez social de los estudios, las intervenciones basadas en el uso de TIC deben llevarse a cabo en entornos naturales para las personas con TEA, como por ejemplo la casa propia o la escuela, ya que es el entorno donde ejecutan de forma natural muchas de las habilidades que se les pretende enseñar. Contar con la participación de un profesional y/o cuidador que conoce a la persona con TEA, y viceversa, contribuirá al éxito de la intervención, así como al mantenimiento y generalización de las habilidades aprendidas. Contar además con la participación de otras figuras cercanas a la persona con TEA (e.g., padres, maestros) puede contribuir significativamente al éxito de la intervención, pues estas pueden asesorar acerca de las necesidades, habilidades, preferencias e intereses de la persona con TEA que participa en un estudio.

Un aspecto que quienes intervienen (e.g., maestros, terapeutas) deben valorar es la elección de una TIC que sea accesible, es decir, que esté disponible en el mercado y que su coste se encuentre dentro del margen de su presupuesto, y que sea relativamente fácil de usar sin la necesidad de contar con un técnico especializado. Otro aspecto a valorar es que el uso de la TIC que se elija ya haya sido evaluado y haya resultado eficaz con otras personas con TEA con características similares a la persona con la que se pretende utilizar. Para sacarle el mayor partido posible a una intervención basada en el uso de TIC, se debe considerar la necesidad de dedicar un tiempo hasta que la persona con TEA alcance un nivel adecuado de manejo de esa TIC antes de practicar alguna habilidad en concreto. Practicar cualquier habilidad de comunicación e interacción social, académica o de la vida de la cual se carezca, será beneficioso para la persona con TEA. Sin embargo, debido al impacto que las habilidades de AC tienen sobre otros aspectos clave del desarrollo como la adquisición del lenguaje, la práctica de estas habilidades merece ser valorada e incluso priorizada en el caso de los niños más pequeños. Puesto que el uso de TIC ha resultado efectivo para la mejora de estas habilidades, más estudios en esta línea podrían contribuir al establecimiento futuro de una nueva EBP en el campo de las TIC para personas con TEA.

ACRONYMS

AAC	Alternative and Augmentative Communication
ABA	Applied Behaviour Analysis
ACM	Association for Computing Machinery
ADI-R	Autism Diagnostic Interview, Revised
ADOS-2	Autism Diagnostic Observation Schedule, Second Edition
APA	American Psychiatric Association
AS	Asperger's Syndrome
ASC	Autism Spectrum Condition
ASD	Autism Spectrum Disorder
BERA	British Educational Research Association
BPS	British Psychological Society
BPVS3	British Picture Vocabulary Scale, Third Edition
CARS-2	Childhood Autism Rating Scale, Second Edition
CHI	The ACM International Conference of Human-Computer Interaction
DART	Development Autism Research Technology
DSM (I, II, III, III-R, IV, IV-TR, 5)	Diagnostic and Statistical Manual of Mental Disorders (First Edition, Second Edition, Third Edition, Third Edition Revised, Fourth Edition, Fourth Edition Text Revised, Fifth Edition)
DTT	Discrete Trial Teaching
EBP(s)	Evidence Based Practice(s)
EIBI	Early Intensive Behavioural Intervention
ERIC	Education Resources Information Center
ESCS	Early Social Communication Scales
ESDM	Early Start Denver Model

GARS (2, 3)	Gilliam Autism Rating Scale (Second, Third Edition)
HFA	High-Functioning Autism
HW	Hardware
ICD-10	International Statistical Classification of Diseases and related health problems, Tenth Revision
ID	Intellectual Disability
IDEA	Inventario De Espectro Autista
IDW(s)	Interactive Digital Whiteboard(s)
IF	Impact Factor
IJA	Initiating Joint Attention
IMFAR	International Meeting for Autism Research
IT(s)	Innovative Technology(ies)
ITASD	International Conference on Innovative Technologies for people with Autism Spectrum Disorder
IOA	Inter-observer agreement
JA	Joint Attention
JAML	Joint Attention-Mediated Learning
JASPER	Joint Attention, Symbolic Play Engagement and Regulation
JCR	Journal Citation Reports
Leiter (2, 3)	Leiter International Performance Scale (Second, Third Edition
LFA	Low-Functioning Autism
M-CHAT-R/F	Modified Checklist for Autism in Toddlers, Revised with Follow-Up
MoD	Medium of Delivery
NIMH	National Institute of Mental Health
OS	Operative System
PECS	Picture Exchange Communication System

PC(s)	Personal Computer(s)
PDD	Pervasive Developmental Disorder
PDD-NOS	Pervasive Developmental Disorder Not Otherwise Specified
PDMS-2	Peabody Developmental Motor Scales, Second Edition
PhD	Doctor of Philosophy
PPVT-4	Peabody Picture Vocabulary Test, Fourth Edition
PRT	Pivotal Response Trial
RCT(s)	Randomised Controlled Trial(s)
RDI	Relationship Development Intervention
RDoC	Research Domain Criteria
RJA	Responding to Joint Attention
SCERTS	Social Communication, Emotional Regulation, Transactional Support model
SCQ	Social Communication Questionnaire
SGD(s)	Speech Generating Device(s)
SSD(s)	Single-Subject Design(s)
SW	Software
TD	Typically developing
TEA	Trastorno del Espectro Autista
TEACCH	Treatment and Education of Autistic and related Communication Handicapped Children
TMI(s)	Technology-Mediated Intervention(s)
TVIP	Test de Vocabulario en Imágenes Peabody
UCLA	University of California, Los Angeles
WHO	World Health Organization
WISC-IV	Wechsler Intelligence Scale for Children, Fourth Edition
WoS	Web of Science

PREFACE

This thesis has been developed in the framework of a competitive predoctoral scholarship, *Atracció de Talent*, awarded to the author of this thesis and funded by the Universitat de València between February 2012 and January 2016.

The research work has been developed at the Autism and Technologies Laboratory at the Research Institute on Robotics and Information and Communication Technologies (IRTIC) of the Universitat de València, under the supervision of the director, Gerardo Herrera, and the co-directors of this thesis: Dr Antonio Ferrer (Senior Lecturer at the Faculty of Psychology of the Universitat de València) and Dr Lila Kossyvaki (Lecturer at the School of Education of the University of Birmingham).

Outline

The principal aim of this thesis consists of reviewing the features and analysing the impact and quality of technology-mediated intervention studies for individuals with Autism Spectrum Disorder. This thesis includes three separated studies, which are interconnected. The outcomes of Study 1 have facilitated the development of Study 2, and the outcomes of Study 1 and Study 2 have significantly influenced the development of Study 3.

The manuscript is structured in five chapters. In the general introduction (Chapter 1), a theoretical framework is described including a brief review of four principal themes: (a) Autism Spectrum Disorder, (b) joint attention, (c) technology and (d) evidence-based practice. Each theme focuses on the points that are principal to follow the content of the three studies.

Study 1 (Chapter 2) is a systematic review in which the features of 178 technology-mediated intervention studies for individuals with Autism Spectrum Disorder are examined. The idea of this work was born in the summer of 2013 during an internship the author did at the School of Education of the University of Birmingham in UK in collaboration with Dr Lila Kossyvaki and Dr Marilena Mademtzi, and under the supervision of Dr Karen Guldberg (director of the Autism Centre for Education and Research, ACER). Kossyvaki, Mademtzi, Guldberg and Pérez-Fuster, together with Gerardo Herrera, felt the need of reviewing the existent literature on innovative technologies for people with Autism Spectrum Disorder. As a result, they developed an initial systematic method for the search, selection and extraction of information from a sample of empirical studies that has contributed to the final and more comprehensive methodological framework developed in this study.

Study 2 (Chapter 3) is a systematic review in which the features, impact and quality of five technology-mediated intervention studies for enhancing joint attention skills in individuals with Autism Spectrum Disorder are evaluated. A factor that enormously motivated and contributed to this study is the expertise that the author acquired in the topic of systematic reviews and meta-analyses as well as evidence-based practices during the completion of a Master's degree in Methodology for the Behavioural Sciences and Health under the supervision of Dr Hilda Gambara at the Universidad Autónoma de Madrid.

Study 3 (Chapter 4) is a technology-mediated intervention study for enhancing joint attention skills in seven children with Autism Spectrum Disorder. The motivation of this study is the need for enhancing core skills such as joint attention given the role it plays on the general development and learning outcomes of children with ASD together with the experience acquired by the author as an advanced trainee of the Early Start Denver Model (Rogers & Dawson, 2010) and five years of working with young children with Autism Spectrum Disorder.

In the final conclusions (Chapter 5), a summary of the main findings and implications for future research and practice of the three studies as well as some last considerations are provided.

The principal contribution of this thesis is:

- To describe an overview of technology-mediated intervention studies for individuals with Autism Spectrum Disorder in order to provide a large list of empirical studies with valuable descriptive information, which can be used for future empirical and review studies (Study 1).
- To report on the rigor and strength of previous technology-mediated intervention studies by means of quality indicators, which can be used for the promotion of evidence-based practices in the field (Study 2).
- To carry out a novel technology-mediated intervention study which shows effectiveness of a ground-breaking technology for enhancing joint attention skills in individuals with Autism Spectrum Disorder. This study is suitable for future replication studies as well as systematic and meta-analytic reviews (Study 3).

Chapter 1

General introduction

1 Introduction

The use of innovative technologies to enhance a wide range of skills in individuals with Autism Spectrum Disorder has been gradually increasing in recent years. This increase has triggered an exponential growth in the number of publications on technology-mediated intervention studies. The principal aims of this thesis were to review the features and to analyse the impact and quality of previous technology-mediated intervention studies and of a novel empirical study for individuals with ASD. In order to achieve these aims, three interconnected studies were conducted.

The objective of Study 1 was to carry out a systematic review for describing the current trends in technology-mediated interventions for individuals with Autism Spectrum Disorder. The objective of Study 2 was to carry out a systematic review for describing technology-mediated intervention studies which focused on the enhancement of joint attention skills in individuals with Autism Spectrum Disorder, and for determining the research quality and the level of evidence achieved by these studies. The objective of Study 3 was to explore the impact of a technology-mediated intervention study on the enhancement of joint attention skills in children with Autism Spectrum Disorder.

This chapter presents a theoretical framework that encompasses the principal themes of the three studies: Autism Spectrum Disorder, joint attention skills, technology and the concept of evidence-based practice. The first theme *Autism Spectrum Disorder* starts with a brief history of this concept including a description of its symptoms as described by the most widely used diagnostic criteria tools. It continues with a description of the main early developmental differences between typically developing individuals and individuals with Autism Spectrum Disorder, which serves as a general framework for the more specific second theme, joint attention. This first theme also includes a description of the most widespread assessment tools for diagnosing Autism Spectrum Disorder and establishing levels of severity. This information is important for some of the arguments that are later given to the findings of Study 1 and Study 2 as well as for the materials chosen in Study 3. Finally, a brief introduction to the most well-known interventions for individuals with Autism Spectrum Disorder is given as a general framework of the teaching theories and strategies that are behind the interventions that focus on joint attention skills and are used in Study 3.

The second theme *joint attention* includes the definition of this group of skills, which are the focus of Study 2 and Study 3, and how these develop in individuals with Autism Spectrum Disorder. A number of assessment tools for evaluating joint attention skills and interventions applied for enhancing these skills, which are also referred to in Study 2 and, more thoroughly explained in Study 3, are also introduced in this section. The third theme *technology* describes the type of technology that is referred to in this thesis and the features that supposedly make it highly attractive for many individuals with Autism Spectrum Disorder. A brief summary of research on the use of technology with individuals with Autism Spectrum Disorder is also given. Since the aim of Study 1 and Study 2 was to carry out a systematic review and this is the method used in many studies for summarizing the results of previous technology-mediated intervention studies, the different types of literature reviews are briefly presented in this section. Finally, the role that time plays in the development of technologies and the conduction of technology-mediated intervention studies is introduced as a relevant fact to consider throughout this thesis. Finally, the fourth theme *evidence-based practice* defines this term, which is notably mentioned in the discussion of Study 1 and constitutes an important part of Study 2 and Study 3.

2 Autism Spectrum Disorder

2.1 A brief history of the concept of Autism Spectrum Disorder

At Johns Hopkins Hospital (Maryland, US) and the University of Vienna (Austria), Kanner (1943) and Asperger (1944), respectively and independently, reported evidence of the distinct syndrome of what is currently called Autism Spectrum Disorder (ASD). On the one hand, Kanner, an Austrian-American psychiatrist and physician, published an extensive report in 1943 (i.e., *Autistic Disturbances of Affective Contact*) in which he described 11 children who had a "powerful desire for aloneness" (p. 249) and "insistence on sameness" (p. 245). These characteristics were later unified under the term *early infantile autism*. On the other hand, Asperger, an Austrian paediatrician, published in 1944 the first definition of what would be later known as Asperger's Syndrome (AS) (Wing, 1981) after he described four boys who were highly intelligent but had "autistic psychopathy", which included "a lack of empathy, little ability to form friendships, one-sided conversation, intense absorption in a special interest and clumsy movements" (Attwood, 1998, p. 11).

Some years later, Wing and Gould published in 1979 a landmark study in the UK of 173 children, only some of which would fit Kanner's 1943 criteria for autism and Asperger's 1944 criteria for AS, "but there was a huge collection in the middle who could not be put into either category. Very few fitted AS, because they virtually all had an intelligence quotient of under 60 and none were mainstreamed" (Volkmar, 2013, pp. 3382-3383). From their findings, Wing and Gould assumed that there was a "symptom heterogeneity" and concluded that there was clearly a "broader autism phenotype", argument that went against the previous categorical or taxonomic view of autism. This inspired them to introduce the concept of the *triad of impairments* that would be common to all individuals with autism, who are in a "continuous dimension" experiencing deficits in (a) social relations, (b) communication and (c) imagination. This concept has had since then a high impact in research and practice and it is still widely used nowadays.

Only one year after, the American Psychiatric Association (APA) published for the first time separate diagnostic criteria for autism in the Diagnostic and Statistical Manual of Mental Disorders (DSM), Third Edition (DSM-III, 1980), which in previous editions (i.e., DSM-I, 1952; DSM-II, 1968) appeared defined under criteria for schizophrenia. The disorder had the name proposed by Kanner (i.e., Infantile Autism) and was mainly based on the features he had previously described. This consisted of six diagnostic criteria: (a) onset before 30 months of age, (b) pervasive lack of responsiveness to other people, (c) gross deficits in language development, (d) if speech was present, peculiar speech patterns such as immediate and delayed echolalia, metaphorical language, pronominal reversal, (e) bizarre responses to various aspects of the environment, and (f) absence of delusions, hallucinations, loosening of associations, and incoherence as in schizophrenia. As a novelty, DSM-III included the possibility of having the disorder after a typical development within the first 30 months of life (i.e., it was not necessarily innate) and described the symptoms as persistent and potentially disabling.

Seven years later, in the revised version of the DSM-III (DSM-III-R; APA, 1987), the term changed to *Autistic Disorder* and included more diagnostic criteria (i.e., from six in the DSM-III to 16 in the DSM-III-R) as a result of an explosion of research studies conducted by clinical and developmental scientists interested in the social nature of autism (Howlin, 1986). The 16 diagnostic criteria were distributed in three categories: (a) qualitative impairment in reciprocal social interaction, (b) qualitative impairment in verbal and nonverbal communication and in imaginative activity, (c) markedly restricted repertoire of activities and interests.

The same diagnostic label (i.e., autistic disorder) and three very similar categories, although with less criteria items (i.e., 12 instead of 16) were defined in the DSM-IV (APA, 1994) and DSM-IV-TR (APA, 2000). However, in these last two versions Autistic Disorder was grouped –together with *Rett's Disorder*, *Childhood Disintegrative Disorder*, *Asperger's Disorder* and *Pervasive Developmental Disorder Not Otherwise Specified* (PDD-NOS)– under the umbrella category of *Pervasive Developmental Disorders* (PDD). More precisely, eight criteria items were defined for Asperger Disorder which were split into two broad categories: (a) qualitative impairment in social interaction, and (b) restricted repetitive and stereotyped patterns of behaviour, interests and activities.

The World Health Organization (WHO) published in 1992 the 10th revision of the International Statistical Classification of Diseases and related health problems (ICD-10) which includes the diagnoses of Childhood Autism and AS – together with *Atypical Autism*, *Rett's Syndrome*, *Other Childhood Disintegrative Disorder, Overactive Disorder associated with mental retardation and stereotyped movements, Other PDD* and *PDD, unspecified*– also under the umbrella category of PDD, and describes similar criteria to the APA's DSM-IV-TR.

Hence, Autistic Disorder (or Childhood Autism) and Asperger's Disorder (or AS) diagnostic labels have been widely used by clinicians, teachers, parents and individuals with these diagnoses for years with a rather clear difference in between the two diagnoses: individuals with Asperger Disorder did not have delay in language development.

The biggest change with regard to diagnostic labels arrived with the introduction of the DSM-5 (APA, 2013), which renames the umbrella category of PDD into ASD and defines a unique set of diagnostic criteria that covers the previous diagnoses of Autistic Disorder, Asperger's Disorder and even PDD-NOS, although this one can also fall under the criteria defined for *Social Communication Disorder*. Thus, individuals who used to be diagnosed with Autistic Disorder or Asperger Disorder are now all diagnosed with ASD, and their language and cognitive abilities are specified within the diagnosis of ASD. Moreover, severity levels for social communication and restricted, repetitive behaviours are scored from one to three according to the support needed by the individual. The DSM-5's diagnostic criteria for ASD, as well as the definition for each severity level, are presented in Figures 1-2.

Autism Spectrum Disorder

Autism Spectrum Disorder

Diagnostic Criteria **299.00 (F84.0)**

A. Persistent deficits in social communication and social interaction across multiple contexts, as manifested by the following, currently or by history (examples are illustrative, not exhaustive; see text):

1. Deficits in social-emotional reciprocity, ranging, for example, from abnormal social approach and failure of normal back-and-forth conversation; to reduced sharing of interests, emotions, or affect; to failure to initiate or respond to social interactions.
2. Deficits in nonverbal communicative behaviors used for social interaction, ranging, for example, from poorly integrated verbal and nonverbal communication; to abnormalities in eye contact and body language or deficits in understanding and use of gestures; to a total lack of facial expressions and nonverbal communication.
3. Deficits in developing, maintaining, and understanding relationships, ranging, for example, from difficulties adjusting behavior to suit various social contexts; to difficulties in sharing imaginative play or in making friends; to absence of interest in peers.

Specify current severity:

Severity is based on social communication impairments and restricted, repetitive patterns of behavior (seeTable 2).

B. Restricted, repetitive patterns of behavior, interests, or activities, as manifested by at least two of the following, currently or by history (examples are illustrative, not exhaustive; see text):

1. Stereotyped or repetitive motor movements, use of objects, or speech (e.g., simple motor stereotypies, lining up toys or flipping objects, echolalia, idiosyncratic phrases).
2. Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior (e.g., extreme distress at small changes, difficulties with transitions, rigid thinking patterns, greeting rituals, need to take same route or eat same food every day).
3. Highly restricted, fixated interests that are abnormal in intensity or focus (e.g., strong attachment to or preoccupation with unusual objects, excessively circumscribed or perseverative interests).
4. Hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment (e.g., apparent indifference to pain/temperature, adverse response to specific sounds or textures, excessive smelling or touching of objects, visual fascination with lights or movement).

Specify current severity:

Severity is based on social communication impairments and restricted, repetitive patterns of behavior (see Table 2).

C. Symptoms must be present in the early developmental period (but may not become fully manifest until social demands exceed limited capacities, or may be masked by learned strategies in later life).

D. Symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning.

E. These disturbances are not better explained by intellectual disability (intellectual developmental disorder) or global developmental delay. Intellectual disability and autism spectrum disorder frequently co-occur; to make comorbid diagnoses of autism spectrum disorder and intellectual disability, social communication should be below that expected for general developmental level.

Note: Individuals with a well-established DSM-IV diagnosis of autistic disorder, Asperger's disorder, or pervasive developmental disorder not otherwise specified should be given the diagnosis of autism spectrum disorder. Individuals who have marked deficits in social communication, but whose symptoms do not otherwise meet criteria for autism spectrum disorder, should be evaluated for social (pragmatic) communication disorder.

Specify if:

With or without accompanying intellectual impairment
With or without accompanying language impairment

Figure 1. Diagnostic criteria for ASD. Adopted from "DSM-5", by APA, 2013, pp. 50-51. Copyright 2013 by the APA.

Severity level	Social communication	Restricted, repetitive behaviors
Level 3 "Requiring very substantial support"	Severe deficits in verbal and nonverbal social communication skills cause severe impairments in functioning, very limited initiation of social interactions, and minimal response to social overtures from others. For example, a person with few words of intelligible speech who rarely initiates interaction and, when he or she does, makes unusual approaches to meet needs only and responds to only very direct social approaches.	Inflexibility of behavior, extreme difficulty coping with change, or other restricted/repetitive behaviors markedly interfere with functioning in all spheres. Great distress/difficulty changing focus or action.
Level 2 "Requiring substantial support"	Marked deficits in verbal and nonverbal social communication skills; social impairments apparent even with supports in place; limited initiation of social interactions; and reduced or abnormal responses to social overtures from others. For example, a person who speaks simple sentences, whose interaction is limited to narrow special interests, and who has markedly odd nonverbal communication.	Inflexibility of behavior, difficulty coping with change, or other restricted/repetitive behaviors appear frequently enough to be obvious to the casual observer and interfere with functioning in a variety of contexts. Distress and/or difficulty changing focus or action.
Level 1 "Requiring support"	Without supports in place, deficits in social communication cause noticeable impairments. Difficulty initiating social interactions, and clear examples of atypical or unsuccessful responses to social overtures of others. May appear to have decreased interest in social interactions. For example, a person who is able to speak in full sentences and engages in communication but whose to-and-fro conversation with others fails, and whose attempts to make friends are odd and typically unsuccessful.	Inflexibility of behavior causes significant interference with functioning in one or more contexts. Difficulty switching between activities. Problems of organization and planning hamper independence.

Figure 2. Severity levels for ASD. Adopted from "DSM-5", by APA, 2013, p. 52. Copyright 2013 by the APA.

After having briefly described the history of the concept of ASD, the author of this thesis (hereafter, referred to as *the researcher*) would like to dedicate a few lines for concisely explaining the reasons why she is using the term ASD henceforth to refer to individuals who are on the autism spectrum. Firstly, *autism* is a term that has been widely used not always including individuals with higher language and cognitive abilities. Secondly, the term *autistic* is a qualifier that, to many people's sensitivity, shadows individuals' abilities. Thirdly, using the term *on the autism spectrum* was considered. However, this is a fairly long term to be repeatedly mentioned throughout the manuscript. Lastly, the term ASD, as described by the APA in the DSM-5, includes all individuals on the autism spectrum, with and without language difficulties, and with and without intellectual disability (ID). Moreover, the word *disorder*, which is a medical term that diverges from the psychological and educational approach of this thesis, remains to some extent unnoticed with the use of the acronym ASD. Additionally, the researcher learnt from experiences in schools and homes that the term TEA (i.e., *Trastorno del Espectro Autista*), which is the equivalent to ASD in Spanish language, was the preferred term for many families to be used with their children who are on the autism spectrum.

2.2 Core differences in the early development of typical and ASD children

To understand and teach individuals with ASD it is necessary to consider the emotional, cognitive and social development seen in typically developing (TD) children. If children with ASD have difficulties in different developmental areas such as social interaction, verbal language, emotions, symbolic and imaginative play, is because all these functions are closely interconnected in the typical development. Such interconnection was defined by the Spanish psychologist and cognitive scientist Rivière (1990) as *racimo funcional*, term that could be translated into English as *functional bunch*, in which each grape of the bunch represents an interconnected function. Thus, understanding the typical development of these interrelated functions is principal to understanding and later defining learning goals in individuals with ASD.

TD individuals are *social animals* since they are born. In the very first weeks of life, they show higher preferences for social stimuli offered by humans, pre-imitative behaviours and patterns of interactive synchrony (Condon & Sander, 1974), giving the first evidences of harmony in between their behaviour and carers' behaviour. On the second and third months of life, TD infants tend to reflect carers' emotions on their own emotional expressions; their facial gestures act as a mirror of what they see in carers' faces. This function was defined as *primary intersubjectivity* by Trevarthen (1980) and basically refers to the ability of the infant for sharing, to some extent, the internal world of others through their emotional system and empathy. It is known that the infant not only can express a facial gesture but also can experience the emotion that a gesture represents. So, when a father smiles to his daughter, the daughter is expected to respond with a smile simultaneously experiencing the emotion of being happy. Thus, father and daughter are having the same emotional experience that was initially triggered by the father's smile. This ability of empathising with others' emotions is an essential motivation for infants' development that most infants with a later diagnosis of ASD lack.

Apart from the experience of sharing emotions, there is another important reason why TD infants feel so attracted to social stimuli offered by humans. This is because humans give responses that are contingent to infant's behaviour. According to Watson (1979), the perception of contingencies is a relevant factor for the development of infants' social behaviour. Moreover, the ability of perceiving contingencies is a requirement for the infant to be able to anticipate others' behaviours in sequences of action. This ability for anticipating is also closely related to the competencies of remembering and recognising familiar people. All these interrelated abilities are generally developed towards the fifth or sixth months of life, and facilitate the development of an intense attachment of the infant to the carers. Infants who are later diagnosed with ASD tend to develop these abilities with a relative delay.

Starting on the seventh or eighth months, TD infants show clear attachment behaviours, abilities for anticipating and interest for exploring objects. These are three decisive factors for an adequate development of communicative behaviours that are intended to (a) make requests (also called *protoimperative behaviours*), and (b) share the experience and the interest for an object or event (also called *protodeclarative behaviours* and, more recently, joint attention) (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). There is an important functional difference in these two groups of behaviours: the function of the protoimperative behaviours is to get something beyond the communication (e.g., to be held in their mother's arms), whereas the function of the protodeclarative behaviours is to communicate sharing interests and experiences with others (e.g., shaking a rattle while looking at their mother's eyes). A TD twelve-month old infant highly shows both protoimperative and protodeclarative behaviours. However, the lack of protodeclarative behaviours in this stage of the development is probably the clearest feature of infants who are later diagnosed with ASD, especially with additional language difficulties (Charman, 2003; Curcio, 1978; Wetherby, 1986; Rivière, Belinchón, Pfeiffer, & Sarriá, 1988).

The fact that protodeclarative behaviours do not usually develop at the same time in ASD as in TD infants suggests that there is a new level of intersubjectivity (Tomasello, 1995). In order to reach this new level, infants need to have the ability to perceive that other individuals are like them: individuals who are able to (a) have and share experiences with them, (b) be interested in things they are interested in, (c) pay attention to things they are paying attention to, (d) perceive what they are perceiving, etc. In other words, understanding that other individuals are human beings able to think and feel, and who they can share with wishes, expectations, interests, believes, etc. By learning all these social meanings towards the end of the first year, a TD infant has a substantial implicit understanding of the surrounding social world.

In the case of individuals who are later diagnosed with ASD, Hobson (1993) described the lack of these abilities as a “limited concept of persons” and Baron-Cohen, Leslie, and Frith (1985) described it as a “child’s impaired Theory of Mind (ToM)”. According to Hobson, individuals with ASD have a limited concept of the nature of persons as having subjective experiences and psychological orientations to the world, whereas Baron-Cohen and his colleagues had a focus on infants’ limited understanding of “beliefs”. These two theories converge in suggesting that what may be common to most if not all individuals with ASD, is a certain specific limitation in understanding the nature of people’s mental states. When the evolution and development of these abilities are limited, the development of symbolic understanding (i.e., communicative interactions may represent an absent object) and language are inevitably affected because they are intended to serve to the communicative functions. This situation takes the infants to a vicious circle in which they do not develop communicative systems, symbolic understanding and language because the others’ world is perceived as obscure and highly unpredictable. Because they do not develop symbolic understanding and language, they lack the instruments they need to connect with the others’ internal world. Consequently, their own world often lacks meaning.

The symptoms of ASD which have been described in the first section of this chapter and the difficulties in the development that have been depicted in this section have served as theoretical framework for the design of assessment tools that are intended to diagnose the presence and level of severity of ASD. The current versions of the most widespread assessment tools which have been considered the *gold standard* for the evaluation and diagnosis of ASD (Díez-Cuervo et al., 2005), are briefly presented in the following section.

2.3 ASD assessment tools

There are assessment tools that have been specifically designed for diagnosing ASD, others for diagnosing and establishing the severity level of ASD, and some others for screening for symptoms which are associated with ASD.

2.3.1 Assessment tools for diagnosing ASD

The Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012). This is a standardised behavioural observation and coding tool that allows to accurately assess and diagnose ASD across ages (from toddlers to adults), developmental levels and language skills. This consists of five modules, each requiring 30 to 45 minutes to administer: (a) the toddler module, which is for pre-verbal or single words from 12 to 30 months old children; (b) the module 1, which is for pre-verbal or single words 31 months and older children; (c) module 2, which is for phrase speech children; (d) module 3, which is for fluent speech children and adolescents; and (e) module 4, which is for fluent speech adolescents and adults.

The Autism Diagnostic Interview, Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003). This is a standardised interview and response coding tool which is useful for diagnosing ASD and planning intervention. The interview is usually administered to parents or carers who are familiar with the developmental history and current behaviour of the individual being evaluated. This can be used to assess both children and adults, as long as their mental age is above 2 years old. Composed of 93 items, the ADI-R focuses on three functional domains: (a) language/communication, (b) reciprocal social interactions, (c) restricted, repetitive, and stereotyped behaviours and interests. It requires from 90 to 150 minutes, including scoring, to administer.

2.3.2 Assessment tools for diagnosing and establishing severity levels of ASD

The Childhood Autism Rating Scale, Second Edition (CARS-2; Schopler, Van Bourgondien, Wellman, & Love, 2010). This is a two 15-item rating scales to be completed by a clinician (a standard version and a high-functioning version) and a parent/carer questionnaire which help to identify children with ASD and determine symptom severity (i.e., mild, moderate, severe) through quantifiable ratings based on direct observation. This can be used to assess individuals of 2 years of age and older. Once the information to make the ratings has been collected, it requires from five to 10 minutes to administer.

The Gilliam Autism Rating Scale, Third Edition (GARS-3; Gilliam, 2013). Based on the DSM-5 diagnostic criteria for ASD, this updated instrument allows to assist teachers, parents and clinicians in identifying ASD in individuals and measuring its severity. This consists of 56 items describing the characteristic behaviours of people with ASD. The items are grouped into six subscales: (a) restrictive, repetitive behaviours; (b) social interaction; (c) social communication; (d) emotional responses; (e) cognitive style; and (f) maladaptive speech. This can be used to assess individuals from 2 to 22 years of age requiring from five to 10 minutes to administer.

Rivière (2002), based on the triad of impairments of Wing and Gould (1979), developed in Spain the *Inventario de Espectro Autista* (IDEA), a tool which helps to evaluate the severity of the symptoms of ASD. This consists of 12 dimensions distributed in four subscales: (a) social, (b) communication and language, (c) anticipation and flexibility, and (d) symbolic understanding, and requires to have a profound knowledge of the person that is being evaluated.

2.3.3 Assessment tools for screening for ASD symptoms

The Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). This is a brief instrument deriving from the ADI-R which helps to evaluate communication skills and social functioning in children who may have ASD. Completed by a parent or other primary carer in less than 10 minutes, this is a cost-effective way to determine whether an individual should be referred for a complete diagnostic evaluation. This can be used to evaluate anyone over age 4, as long as his/her mental age exceeds 2 years. It is available in two forms (i.e., *Lifetime*, which focuses on the child's entire developmental history, and *Current*, which looks at the child's behaviour over the most recent 3-month period) each composed of 40 yes-or-no questions. Both forms can be given directly to the parent/carer, who can answer the questions without supervision.

The Modified Checklist for Autism in Toddlers, Revised with Follow-Up (M-CHAT-R/F; Robins, Fein, & Barton, 2009). This is a two-stage parent-report screening tool which consists of 20 pass-fail items to assess risk for ASD in children between 16 and 30 months of age.

Establishing a diagnosis and determining the severity level of the symptoms of a given child is an important starting point for any clinician before conducting any type of intervention. However, for adequately selecting psychological and educational intervention methods or defining specific learning goals, it is necessary to do a complete evaluation of the child also including important aspects such as child's cognitive, motor and language skills.

There is a vast number of available tools for evaluating each of these abilities. For instance, the *Wechsler Intelligence Scale for Children, Fourth Edition* (WISC-IV; Wechsler, 2003) has been designed for measuring the intellectual ability of a 6-16 years old child, providing information for (a) verbal comprehension, (b) perceptual reasoning, (c) working memory, and (d) processing speed. Besides, the *Leiter International Performance Scale, Third Edition* (Leiter-3; Roid, Miller, Pomplun, & Koch, 2013) offers a completely nonverbal measure of intelligence that is suitable for use with minimally verbal individuals from 3 years old, providing information for cognitive, attentional, and neuropsychological abilities. Further, the *Mullen Scales of Early Learning* (Mullen, 1995) is a tool for measuring cognitive ability, language, and motor development from birth to 68-month infants, providing information on (a) gross motor, (b) visual reception, (c) fine motor, (d) receptive language, and (e) expressive language. For specifically evaluating motor skills the *Peabody Developmental Motor Scales, Second Edition* (PDMS-2; Folio & Fewell, 2000) is suitable for use with from birth up to 5 years old children. Likewise, specific tools have been designed for the evaluation of important aspects of language development such as receptive vocabulary: the *Peabody Picture Vocabulary Test, Fourth Edition* (PPVT-4; Dunn & Dunn, 2007) is used with Standard American English speakers from 2 years old, the *British Picture Vocabulary Scale, Third Edition* (BPVS3; Dunn & Dunn, 2009) is used with Standard British English speakers from 3 years up to 16 years of age, and the *Test de Vocabulario en Imágenes Peabody* (TVIP; Dunn, Padilla, Lugo, & Dunn, 1986) is used with Spanish speakers from 2 years up to 17 years of age.

Administering the tools that are needed for obtaining a complete and updated report of the symptoms, abilities and difficulties of a child, highly contributes to the choice of a potentially successful intervention method. Moreover, an unstructured observation of the child in a natural environment is also needed for becoming aware of the child’s strengths, preferences and interests. In the following section, the most widespread intervention approaches for individuals with ASD are briefly presented.

2.4 Intervention methods used for individuals with ASD

There are different intervention methods to cover the individuals’ needs of (a) learning new behaviours, mastering existing behaviours and reducing undesired behaviours (e.g., self-injury behaviours); (b) having access to an adequate communication system; and (c) learning in an organised and structured environment.

2.4.1 Teaching new behaviours, mastering existing behaviours and reducing undesired behaviours

Traditionally, *Applied Behaviour Analysis* (ABA) has been widely used and is considered one of the most effective techniques for behaviour modification in individuals with ASD (Reichow & Wolery, 2009). ABA is founded on the science of learning set in the early 1900s including the *classical conditioning* of Watson and Pavlov, the *instrumental conditioning* of Thorndike and the *operant conditioning* of Skinner. According to the basic principles of ABA, three components are necessary for learning. First, some stimulus must serve as a cue for the child to respond and the child must attend to this stimulus event. Second, the child must show a behaviour immediately following the stimulus. Third, the child must experience some type of consequence or feedback that marks a correct performance (Lovaas, 1987). Over time, it is expected to see the child emit the new behaviour more quickly, frequently, and easily in response to the stimulus, and to use the new skill or behaviour in a widening range of appropriate contexts (i.e., generalization).

One of the first intervention methods that was applied to individuals with ASD (when they were still referred to as individuals with a type of schizophrenia) was developed by Lovaas et al. at the University of California, Los Angeles (UCLA), has an ABA approach, and is called *Discrete Trial Teaching* (DTT) or *Lovaas model* (Lovaas, Berberich, Perloff, & Schaeffer, 1966; Lovaas, Freitag, Gold, & Kassoria, 1965). The DTT version for younger children is known as *Early Intensive Behavioural Intervention* (EIBI). Basic ABA practices of effective teaching used in DTT and EIBI are: (a) capturing the person’s attention until the instruction has been given, the action accomplished, and the reward delivered; (b) delivering teaching within a contingent antecedent-behaviour-consequence sequence; (c) prompting desired behaviours under specified stimulus conditions, (d) managing consequences including reinforcement, punishment and extinction; (e) fading prompts to avoid prompt dependence and promote generalization of the skills; (f) gradually shape the immature behaviour into a more mature behaviour; (g) chaining behaviours (i.e., individual actions that become linked together to form behaviour sequences, (h) functional assessment of behaviour (i.e., a process for determining the functions of a behaviour) or functional analysis of behaviour (i.e., a process for causally define the variables that underlie a behaviour). Although these practices have been found to be effective in increasing social communication and interaction skills and reducing undesired behaviours, they have been questioned due to (a) the limited generalisation of the skills and (b) the little importance that is given to the spontaneity and naturalness of the person who is being taught (Eldevik et al., 2009; Makrygianni & Reed, 2010; Peters-Scheffer, Didden, Korzilius, & Sturmey, 2011; Reichow, 2012; Spreckley & Boyd, 2009; Virués-Ortega, 2010).

Pivotal Response Trial (PRT) is another intervention method based on the principles of ABA and was first published in the 1980s by Koegel and Koegel (Koegel & Koegel, 1988; Koegel & Williams, 1980; Koegel, O'Dell, & Koegel, 1987) and more recently by Schreibman (Ingersoll & Schreibman, 2006; Schreibman & Koegel, 2005). The PRT approach suggests that two behaviours appear to be pivotal in improving a wide range of behaviours and in determining later adaptive capacities: *motivation* and *response to multiple cues* (Koegel, Koegel, Harrower, & Carter, 1999; Koegel, Koegel, Shoshan, & McNerney, 1999). PRT works to increase motivation by including components such as (a) teaching in a more naturalistic environment, (b) using child-chosen objects as reinforcers, (c) providing opportunities for turn taking, (d) reinforcing attempts, and (e) interspersing maintenance tasks. PRT builds the child's capacity to respond to multiple cues by (a) varying the antecedents, (b) purposely setting up stimuli with multiple cues, and (c) teaching children to emit the same behaviour in response to varying related antecedents. Compared to DTT, PRT techniques result in children with more motivation to perform, better generalization of new skills, more spontaneous responding, and less behaviour difficulties (Ingersoll & Schreibman, 2006). However, PRT is an appropriate teaching method only when the skill to be taught has a direct relationship to a reinforcer (Rogers & Dawson, 2010).

The *Denver Model* is a more comprehensive intervention method which focuses on (a) the affective and relationship-based aspects of the interventionist's work with the child, (b) the emphasis on development of play skills, and (c) the use of communication intervention principles from the field of communication science (Rogers, Herbison, Lewis, Pantone, & Reis, 1986; Rogers & Lewis, 1989). Principles of the Denver Model are: (a) interventionists modulate and optimize child affect, arousal and attentional state; (b) interventionists use positive affect; (c) continuous turn taking and dyadic engagement are provided; (d) interventionists respond sensitively and responsively to child communicative cues; (e) multiple and varied communicative opportunities are given; (f) elaboration of activities; (g) interventionists language is consistently appropriate developmentally and pragmatically for the child's verbal and nonverbal communicative intent and capacity; and (h) transitions between activities are effectively managed.

A more recently intervention method that uses teaching practices and procedures melded together from DTT, PRT and the Denver Model is the *Early Start Denver Model for young children with autism* (ESDM) developed by Rogers and Dawson (2010). The principal aim of this intervention is to engage a child between 7-9 months and 5 years of age in positive emotional experiences with another person, to draw the child's attention to social stimuli, to make such stimuli rewarding for the child, and to foster the child's motivation to continue such activities. By eliciting social and communicative behaviour from the child, it is expected to stimulate and shape his/her neural networks into patterns of greater sensitivity and responsivity to social partners than objects. Principles of the ESDM are: (a) creating positive emotional states in children during social interactions; (b) *joint activities routines* as play activities in which both partners have key roles and build on each other's contributions (Bruner, 1977) are the primary vehicles for teaching; (c) intensive teaching to increase number of learning opportunities; (d) following the principles of positive behaviour approaches (Duda, Dunlap, Fox, Lentini, & Clark, 2004) for replacing unwanted behaviours with more conventional behaviours, rather than eliminating unwanted behaviours per se; (e) family involvement, since parent and family involvement is considered a best practice in early ASD intervention (National Research Council, 2001).

ESDM is a curriculum with four levels that, although defined for a specific chronological age range, are to be used according to each individual's development. Thus, Level 1 is for infants with a developmental age of between nine and 18 months, Level 2 is for infants with a developmental age of between 18 and 24 months, Level 3 is for infants with a developmental age of between 24 and 36 months, and Level 4 is for infants with a developmental age of between 36 and 48 months. Each level includes different items (i.e., distinct skills) for receptive communication, expressive communication, joint attention behaviours, social skills, imitation, cognition, play, fine motor, gross motor and personal independence.

The ESDM most closely resembles to other intervention approaches with a strong emphasis on responsive interactions and a developmental orientation, such as the *Responsive Teaching* (Mahoney & Perales, 2003; Mahoney & Perales, 2005), *DIR/Floortime* (Wieder & Greenspan, 2005), the *Relationship Development Intervention* (RDI; Gutstein & Sheely, 2002), the *Social Communication, Emotional Regulation, Transactional Support* model (SCERTS; Prizant, Wetherby, Rubin, Laurent, & Rydell, 2006), and *Hanen Centre* programs (Coulter & Gallagher, 2001). All these intervention approaches are built on empirical evidence concerning patterns of typical social-communicative development. However, the ESDM uses a more explicit behavioural teaching paradigm, is more data driven, and it covers all developmental domains in its teaching practices, while most of the other models focus on social-communicative development (Rogers & Dawson, 2010). Moreover, only DTT and PRT intervention methods have as large body of research behind them as does the Denver Model and the ESDM (e.g., Dawson et al., 2010; Dawson et al., 2012; Fulton, Eapen, Crncec, Walter, & Rogers, 2014; Vivanti et al., 2014). Finally, the American Academy of Pediatrics identifies DTT, EIBI and the ESDM as the only evidence-based clinical interventions for young children with ASD (Warren et al., 2011).

2.4.2 Providing the child with ASD an adequate communication system

As Grandin (2006) indicated, many individuals with ASD "think in pictures", which makes them to process much easily, and in some cases only, information that is visually presented. So, spoken and written language is not the first option for many people with ASD to communicate with others as it is for TD individuals. Therefore, a number of *Alternative and Augmentative Communication* (AAC) systems have been developed with the years. The *Picture Exchange Communication System* (PECS; Bondy & Frost, 1994) is one of the most widely and effectively used visual system with children with ASD (Flippin, Reszka, & Watson, 2010). As defined by its authors, PECS is a modified ABA program designed for helping children to communicate with pictures. The pictures used may be photographs, or coloured, or black and white, line drawings, and they are usually represented on a *laminated paper-based card*. Children are taught through six phases which help them to gradually build communication (i.e., Phase I-Phase VI). In Phase I they learn to give to the interventionist one card to request an object or event that is represented in that card. Children who complete Phase VI are able to use multiple cards to form phrases that are intended not only to request but also to comment on things or events. The cards that children need for communicating are usually put together, secured by Velcro, and classified according to different criteria, in an individual PECS *communication book*. Children often carry the PECS communication book with a strap over their shoulders in transitions and they leave them nearby at a reachable distance while they are executing any other activity. Therefore, their communication book is their 'voice'. Another tool designed within this intervention method is the *schedule board,* which is suitable for setting up a learner's timetable. This consists of a long schedule board where learners can place the cards of the activities they are going to do during a session or a day. At the end of the schedule board there is a *finished box* where learners place the cards of the activities that have already been completed. This tool facilitates the children with ASD to organise, anticipate and do the transition in between the activities of the session or the day.

2.4.3 Teaching in an organised and structured environment

The PECS schedule board tool recalls the importance of facilitating organization, anticipation and transition in the education of a person with ASD given the difficulties they have for innately developing these abilities (Jordan & Powell, 1995). A widespread and highly effective system that also considers these three aspects, among many others, is the *Treatment and Education of Autistic and related Communication Handicapped Children* (TEACCH) program (Mesibov, Shea, & Schopler, 2005), which is based at the University of North Carolina – Chapel Hill (Virues-Ortega, Julio, & Pastor-Barriuso, 2013). The TEACCH program's major priorities include (a) focusing on each individual's needs, (b) adopting appropriate adaptations, and (c) a broadly based intervention strategy building on each person's existing skills and interests.

The TEACCH program developed an intervention approach called *Structured TEACCHing*, which is not a curriculum, but instead is a framework to support achievement of educational and therapeutic goals. This framework is based on the idea that to effectively teach students with ASD teachers must provide structure. This means teachers should set up the classroom so that students understand where to be, what to do, and how to do it, all as independently as possible. Accordingly, Structured TEACCHing includes (a) physical organization, (b) individualized schedules, (c) work –activity– systems, and (d) visual structure of materials in tasks and activities. The goal of this intervention method is to promote meaningful engagement in activities, flexibility, independence and self-efficacy.

According to *what one wants to intervene on* it will be more adequate to use one intervention approach or another. An interventionist can be more interested in intervening on general aspects that affect individuals with ASD such as language development, motor skills and adaptive behaviours or on more specific ASD core symptoms such as symbolic play, imitation and joint attention (Saldaña, 2016). In a previous section of this chapter the role of joint attention has been described as a protodeclarative behaviour that becomes evident starting from the second semester of the first year of life. This dimension requires special consideration from a neuro-developmental perspective because it is one of the early markers of ASD (Gliga, Jones, Bedford, Charman. & Johnson, 2014).

3 Joint attention

3.1 Definition

Joint attention (hereafter referred to as "JA") can be defined as the shared focus of two individuals on an object or event. JA occurs when one individual gets the attention of another towards an object or event by means of eye-gazing, pointing or other verbal or non-verbal indications. JA is achieved when, for instance, two individuals look at each other's eyes, one of them points to an object, both look at the object and afterword they look at each other's eyes again. It is said then that 'they have shared the experience of that object'. At Oxford University, Scaife and Bruner (1975) reported a preliminary investigation of the extent of the infant's ability to follow changes in adult gaze direction during the first year of life. They found that most eight- to 10-month-old children followed an adult's gaze, and that all 11- to 14-month children did so. This publication, which has been cited by more than a thousand subsequent studies, has been considered the origin of the revolution for the understanding of infant's mind and learning processes (Dunham & Moore, 1995).

All the wealth of knowledge on the role of JA in both TD and ASD individuals has been synthesized by Mundy (2016), who defines JA as follows:

> Joint attention refers to the fluid, exquisitely well-honed human ability to adopt a common point of reference with other people. The name for this dimension of behaviour comes from the observation that prelinguistic infants learn to share information and experiences with other people by coordinating their visual, auditory, or tactile attention on objects or events with these people. Hence joint attention first involves coordinating attention with other people to the external world. However, a dynamic dance between social-cognitive neurodevelopment and practice with joint attention to external objects in early infancy leads to the emergence of the capacity to socially coordinate attention to internal mental objects in later infancy. This internalized cognitive capacity for joint attention, and adopting a common point of reference, is fundamental to learning language, developing collaborative and cooperative behaviour. Moreover, joint attention is also fundamental to our sense of social relatedness and intersubjectivity when it is accompanied by the perception of sharing meaning and experience with another person. (Mundy, 2016, p. viii).

Given this description of JA and considering the differences in the early development of TD and ASD children, it may not come as a surprise that difficulties in JA are amongst the most important characteristics of the development of an infant with ASD.

3.1.1 Initiating JA versus responding to JA

JA has been widely divided into initiating JA (IJA) and responding to JA (RJA) (Charman et al., 1997; Charman et al., 1998; Mundy & Gomes, 1998; Mundy & Newell, 2007). IJA refers to the use of eye contact, gaze shifting and gestures to direct the attention of a social partner to a referent of interest (Franco & Butterworth, 1996; Mundy & Crowson, 1997) while RJA refers to response by gaze following, pointing or showing to enhance social interaction with others (Brooks & Meltzoff, 2005; Leekam, Hunnisett, & Moore, 1998; Sigman & Ruskin, 1999). Particularly, gaze following has been considered an important RJA skill because it contributes to understanding what another is thinking, feeling and intending to do (Frith & Frith, 2001; Meltzoff & Brooks, 2001; Tomasello, 1995) facilitating therefore the development of ToM (Baron-Cohen, 1995; Charman et al., 2000).

3.2 JA and individuals with ASD

3.2.1 JA development in individuals with ASD

3.2.1.1 Pioneering studies

Mundy (at the University of Miami, at the UCLA and now at the UC Davis MIND Institute) and Kasari (at the UCLA) have been two of the researchers that have investigated the most on JA abilities in individuals with ASD until today. Seibert, Hogan, and Mundy (1982) identified JA as one of the principal nonverbal social-communication acts to evaluate on infant behaviour for identifying developmental delays. Mundy, Sigman, Ungerer, and Sherman (1986) said for the first time that difficulties in the early development of infants' ability to coordinate their visual attention with other people (i.e., JA) was a fundamental feature of the early onset of ASD. Four years later, Mundy, Sigman, and Kasari (1990) published another outstanding report in which they stated that gestural nonverbal JA skills significantly predicted language development in children with ASD and thus, JA skills were a fundamental component of exceptional development among young children with ASD.

3.2.1.2 Core differences on the IJA and RJA abilities of TD and ASD infants

Infants typically develop the ability to participate in JA interactions (e.g., coordinated eye gaze) at between six and twelve months of age (Bakeman & Adamson, 1984; Butterworth & Jarret, 1991; Leekam et al., 1998; Mundy & Gomes, 1998) and they successfully gaze follow and point before 24 months of age (Moore & Corkum, 1998; Morissette, Ricard, & Décarie, 1995). However, JA skills have been identified as a profound difficulty among children with ASD (Mundy et al., 1986) which can be present not only at first stages of development but throughout their life span. Research has indicated that IJA and RJA are two distinct JA forms that develop differently –and are associated to different brain patterns (Mundy, Card, & Fox, 2000)–, as individuals grow older (Gillespie-Lynch, Elias, Escudero, Hutman, & Johnson, 2013; Mundy, Sigman, & Kasari, 1994; Nation & Penny, 2008). According to these studies, when infants are at the preverbal stage, significant differences can be observed on the RJA and IJA skills of infants with ASD compared to TD infants, the first being much more affected, especially in the ability for RJA. More precisely, it has been found that children with ASD do not engage in the RJA skills of following gaze, showing and pointing as TD children do (Carpenter, Pennington, & Rogers, 2002; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Paparella, Goods, Freeman, & Kasari, 2011). However, that difficulty with RJA of the children with ASD become less evident as their language or mental age level exceed what is typically observed in 30-month-old children. IJA differences between TD and ASD children, instead, do not appear to begin to remit at 30 months of age but continues through the preschool period and in some cases even through adulthood (Charman, 2003; Dawson et al., 2004; Mundy et al., 1986; Sigman et al., 1999). Therefore, RJA difficulties are critical to many aspects of development in children with ASD, being the early language development the most prominent one (Charman, 2003; Morales et al., 2000), whereas IJA difficulties appear to be more associated to developmentally chronic differences (Gangi, Ibañez, & Messinger, 2014).

3.3 Recognition of the importance of JA in ASD research

Mundy (2016), based on the hundreds of studies that have been published in the last 40 years, indicates that JA appears to be “among the few, if any other, social dimensions of ASD that currently have as much experimental interventions support for their role in mediating learning in children with ASD” (p. 207). He also identifies JA difficulties as a unique dimension of ASD –beginning as early as the first few months of life– and clearly states that no other dimension is more strongly linked to ASD early identification and intervention. JA difficulties do not explain

ASD. It is not a dimension that fully accounts for ASD but it is a dimension that must be included in any full account of ASD.

Nevertheless, there is a lack of consensus in the field on the role and relevance of JA. The National Institute of Mental Health (NIMH), in one of its efforts for advancing in science through a dimensional approach to psychopathology, developed the Research Domain Criteria (RDoC) as an alternative to the use of symptom-based categories of disorders in organizing clinical research. The RDoC approach is designed to identify the brain-behaviour dimensions that are needed for precisely describing all facets of atypical mental development. Once these dimensions are identified, research can then be implemented to determine the subset of which dimensions, and their dynamic interactions in development, are most central to understanding different types of psychopathology. The hope is that starting with dimensions and building up to categories of disorders will lead more directly to targeted treatments for neurodevelopment disorders and psychopathology (Cuthbert & Insel, 2013). The current RDoC system includes five domains and 23 constructs (for a more complete description see https://www.nimh.nih.gov/research-priorities/rdoc/rdoc-constructs.shtml). JA falls within the *Social Communication* construct of the *Systems for Social Processes* domain, but not as a distinct mental function with a specified course of neurodevelopment. Instead, it is designated as a method of measurement for research on *Reception and Production of Facial Communication*.

It is indisputable that JA –as a pivotal skill to human social communication (Adamson, 1995; Charman, 2003)– involves the processing of another person's gaze and other gestures such as head direction as well as the expression and understanding of one's and others' facial affect (Brooks & Meltzoff, 2002; Kasari, Freeman, & Paparella, 2000; Mundy & Crowson, 1997). However, studying face processing is not needed to study JA. In order words, neurocognitive studies do not measure face processing to examine children and adults' protodeclarative pointing (e.g., Brunetti et al., 2014), which is a fundamental JA behaviour. Moreover, cognitive neuroscience studies indicate that JA and face processing are mainly linked to different brain systems (Brunetti et al., 2014; Gordon, Eilbott, Feldman, Pelphrey, & Vander Wyk, 2013). Thus, the brain processes involved in JA may include but are not defined by the processes associated with face processing. This is because the study of JA is the study of the human neurocognitive capacity for social reference (Bates, Camaioni, & Volterra, 1975; Bruner, 1975; Mundy & Newell, 2007; Tomasello, Carpenter, Call, Behne, & Moll, 2005). Humans must practice self-other processing of a shared focus of attention in the first years of life in order to develop neurocognitive means to later engage in the referential function of language and other higher levels of human social communication.

Although JA is not considered to be a dimensional status of ASD within the NIMH RDoC –due to the putative lack in guiding advances in research on the biological basis of ASD–, its relevance is undoubtable (Mundy, 2016). Moreover, developing a deeper appreciation of the nature and measurement of JA over the last four decades has advanced research on diagnosis, early identification, and targeted behavioural interventions for ASD.

3.3.1 Assessment tools for evaluating JA

3.3.1.1 General assessments for evaluating ASD

JA difficulties being identified as one of the earliest symptoms of ASD, it is not surprising that JA skills are included in the current diagnostic criteria for ASD. The DSM-5 (APA, 2013) includes in its criteria *A(1)* (see Figure 1) "Deficits in social-emotional reciprocity, ranging, for example, from abnormal *social approach* and failure of normal back-and-forth conversation; to reduced *sharing of interests, emotions, or affect*; to failure to *initiate or respond to social interactions*" (p. 50). Moreover, the three new severity levels for ASD (see Figure 2) emphasize problems with initiating and responding to social behaviours, from "difficulty initiating social interactions, and clear examples of atypical or unsuccessful responses to social overtures of others" to "limited initiation of social interactions;

and reduced or abnormal responses to social overtures of others" to "very limited initiation of social interactions, and minimal response to social overtures from others" (p. 52). Moreover, the DSM-5 (APA, 2013) recognises the role of JA in the development of ASD: "An early feature of ASD is impaired JA manifested by a lack of pointing, showing, or bringing objects to share interest with others, or failure to follow someone's pointing or eye gaze (p. 54).

Most of the widest used standardised assessments for screening and diagnosing ASD (see pp. 69-71) include items for evaluating JA. The ADOS-2 (Lord et al., 2012) includes on the social affect factor of the toddler module and module 1 (pre-verbal/single words) items such as pointing, gestures, unusual eye contact, showing, spontaneous IJA and RJA. The ADI-R (Rutter, Le Couteur et al., 2003) includes in the factor for "qualitative abnormalities in reciprocal social interaction" a group of items which evaluate the lack of shared enjoyment: "showing and directing attention" (item 52), "offering to share" (item 53), and "seeking to share enjoyment with others" (item 54). The GARS-3 (Gilliam, 2013), in its social interaction subscale, includes items like "Avoids eye contact, looks away when someone looks at him or her" (item 29). The IDEA (Rivière, 2002), in its social subscale, includes an item for evaluating the joint reference abilities obtaining a score that ranges from 0 (there is not a qualitative disorder in the abilities of joint reference) to 8 (complete absence of joint actions and interests for other individuals and their actions). The SCQ (Rutter, Bailey et al., 2003) includes items such as "Does she/he ever spontaneously point at things around her/him just to show you things (not because she/he wants them)?" (item 22), "Does she/he ever show you things that interest her/him to engage your attention?" (item 28), or "If she /he wants something or wants help, does she/he look at you and use gestures with sounds or words to get your attention?" (item 32). Finally, the M-CHAT-R/F (Robins et al., 2009) includes items such as "If you point at something across the room, does your child look at it?" (item 1), "Does your child point with one finger to show you something interesting?" (item 7), "Does your child show you things by bringing them to you or holding them up for you to see - not to get help, but just to share?” (item 9), or “If you turn your head to look at something, does your child look around to see what you are looking at?” (item 16).

3.3.1.2 Targeted assessments for evaluating JA

One of the first thorough measurement systems that were developed to assess development of both expressive (self-initiated) and responsive forms of protodeclarative and protoimperative functions in infancy (from eight to 30 months of age) was the *Early Social Communication Scales* (ESCS). The first version of the ESCS was created by Seibert et al. (1982) at the University of Miami and the current version was published by Mundy et al. (2003). The ESCS is a video recorded structured observation measure of both types of JA (i.e., IJA and RJA) as well as infants’ capacity to coordinate attention to request assistance in obtaining an object or event, or to respond to such requests from others. The ESCS has resulted in organizing precise and reliable observations of JA and social attention coordination that can also guide to early intervention (Seibert et al., 1982).

As infants grow older and develop language, their difficulties in IJA and, especially, RJA may lessen. This may be the reason why JA measures are not included in assessments oriented to older or individuals who have developed speech (e.g., modules 3-4 of the ADOS-2). However, there are individuals with ASD who have IJA and RJA difficulties throughout their childhood and adulthood, regardless of their level of language. For some of them, especially those whose cognitive abilities are not at the lowest level, the ESCS may result a too babyish assessment tool. Yet the lack of measures of JA for older individuals, beyond measures used in imaging studies, appears a significant gap in the field. Latency measures (Jarrold et al., 2013) and eye-tracking measures (Falck-Ytter, Thorup, & Bölte, 2015) are two novel approaches that have been very recently used for JA assessment. Besides, a new tool for measuring JA in older children with ASD based on social engagement measures (Mundy & Acra, 2006) is being currently developed. A very recent study has shown that it may be possible to develop a reliable rating scale for childhood JA and social development (Mundy et al., 2017).

3.3.2 Interventions on JA in individuals with ASD

3.3.2.1 General interventions for individuals with ASD

The teaching methods and techniques which have been described in a previous section of this chapter, are also amongst the most used by researchers and clinicians to enhance JA in individuals with ASD. More precisely, ABA techniques such as prompting, modelling, and reinforcement have been applied for enhancing JA in children with ASD. Martins and Harris (2006) used reinforcing methods for enhancing RJA skills. Taylor and Hoch (2008) used reinforcing plus prompting methods for enhancing IJA and RJA skills. Isaksen and Holth (2009) applied reinforcement, prompting and modelling methods for enhancing IJA and RJA skills. Wong, Kasari, Freeman, and Paparella (2007) used prompting and reinforcement methods for enhancing IJA and RJA skills. Zercher, Hunt, Schuler, and Webster (2001) used modelling methods delivered by peers for enhancing IJA and RJA. All in all, increase in IJA and RJA was obtained through these techniques but generalization was rarely reported. PRT intervention methods delivered by therapists (Jones, Carr, & Feeley, 2006; Whalen & Schreibman, 2003), parents (Jones, 2009; Rocha, Schreibman, & Stahmer, 2007; Vismara & Lyons, 2007), siblings (Ferraioli & Harris, 2011) and peers (Pierce & Schreibman, 1995) have been found to be effective in increasing IJA and RJA skills in children with ASD. They have also been found effective in contributing to collateral advances in language development, imitation, and other social behaviours.

The ESDM curriculum includes in Level 1 (i.e., for 9- to 18-month infants) items for JA behaviours under the categories of receptive communication (e.g., item 6: looks when shown an object and told “Name, look”) and expressive communication (e.g., item 7: makes eye contact to obtain a desired object when adult blocks access/withholds desired object). Level 2 (i.e., for 18- to 24-month infants) has a specific category for targeting JA behaviours which includes eight items (e.g., item 2: responds to “Look” and point by orienting to the indicated distal object/person). Level 3 (i.e., for 24- to 36-month infants) and Level 4 (i.e., for 36- to 48-month infants) include in their respective categories of social skills items that convey JA but are much more complex (e.g., item 12 in Level 3: responds to others’ bids for JA by looking and commenting; item 6 in Level 4: describes an event or experience to peer). This approach has also been found to be effective for increasing IJA and RJA skills in children of between 12 months and 5 years of age with ASD (Rogers et al., 2006; Vismara, Colombi, & Rogers, 2009; Vismara & Rogers, 2008).

3.3.2.2 Targeted interventions for enhancing JA

The *Joint Attention-Mediated Learning* (JAML) (Schert & Odom, 2007) provides methods to principally increase parental responsiveness to their children’s IJA and RJA bids. Two JAML studies reported significant improvements on RJA (Schertz & Odom, 2007; Schertz, Odom, Baggett, & Sideris, 2013).

The *Joint Attention, Symbolic Play Engagement and Regulation* (JASPER) is a theory- and evidence-based targeted approach to early developmental-behavioural intervention for children with ASD which was developed by Kasari at the UCLA in 1997. JASPER is designed to advance development in two dimensions that allow children to become more engaged and active in learning with and from others: JA and symbolic play. It is based on the idea that fostering JA and especially IJA development in children with ASD will improve their capacity for being more engaged to sharing information with other people in social learning opportunities across contexts (Kasari et al., 2000). This is a brief intervention approach (from 20- to 60-minute daily sessions for between five and 12 weeks) that has been found to be highly effective increasing JA as well as language skills in children with ASD. Kasari, Freeman, and Paparella (2006) evaluated the efficacy of JASPER in the framework of an ABA intervention and they found developmental advances in the IJA and RJA skills of the group of children with ASD who were taught with JASPER in comparison to the group of children that only received ABA instructions. Then, Kasari, Paparella, Freeman, and Jahromi (2008) subsequently reported follow-up outcome data on the efficacy of JASPER for improving language learning. They found that the group of children who were taught with JASPER improved in IJA and displayed significantly better expressive language development. They indicated that JASPER improved the intrinsic social learning ability of children with ASD and that this targeted intervention may boost the benefits children receive from other, more comprehensive interventions (with an ABA approach in this case). Two subsequent longitudinal studies (Kasari, Gulsrud, Freeman, Paparella, & Hellemann, 2012; Gulsrud, Hellemann, Freeman, & Kasari, 2014) as well as intervention studies in which JASPER has been delivered by teachers (Lawton & Kasari, 2012) and parents (Kasari, Gulsrud, Paparella, Hellemann, & Berry, 2015; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Kasari, Lawton et al., 2014) have reported effective results in enhancing both IJA and RJA skills in children with ASD.

Finally, Kasari, Kaiser et al. (2014) examined the effects of JASPER in combination with other two interventions (i.e., a naturalistic behaviour intervention and the use of a speech generating device) to foster language responsiveness in minimally verbal 5- to 8-year old children. The results of this study indicated that children who were taught with a combination of the three interventions showed significantly stronger positive effects on social-communicative utterances, use of different words and higher number of comments addressed. This study provides hopeful and helpful evidence that a targeted intervention for JA can (a) have an impact on children’s communicative speech functions and (b) can be combined with other methods to improve effective educational practices for minimally verbal primary age children with ASD (Tager-Flusberg, 2014). Another relevant finding of this study is that adding the use of a speech generation device (i.e., an electronic AAC used to supplement or replace speech or writing, for individuals with special educational needs, enabling them to verbally communicate) in one of the conditions resulted highly effective in facilitating children's language development. This finding takes one to think about the role that the use of innovative technology plays in the learning processes of people with ASD.

4 Technology

Technology is a very broad term that throughout this thesis particularly refers to innovative technologies (ITs) (Goodwin, 2008) such as personal computers (PCs), smartphones, tablets or robots. ITs can be used for numerous purposes including screening and diagnosing, mediating in educational and psychological interventions and providing resources for data collection and analysis. Specifically, this thesis work focuses on technology-mediated interventions (hereinafter referred as "TMI"), term that is defined as the use of ITs for facilitating any learning process.

According to developmental models of early intervention (e.g., ESDM), one of the difficulties in teaching children with ASD is that they may not be interested in a topic or referent chosen by the interventionist. If a child is interested in something in the environment, a *teachable moment* presents itself. The use of ITs can facilitate *per se* teachable moments for many individuals with ASD due to their special affinity for it.

Individuals with ASD tend to be fond of ITs for a number of reasons. Firstly, it is known that many individuals with ASD are good at processing visual information (Grandin, 2006) and in most ITs (e.g., PCs, tablets) the information is visually presented, and can be accompanied by other sensory outputs (e.g., auditory). Individuals with ASD also often have difficulty filtering sensory information that is not salient to their daily interactions (Rutter & Schopler, 1987). Computer screens allow information to be abstracted or limited to only relevant information, supporting so the filtering process. As described in the DSM-5 and is broadly investigated by Bogdashina (2003), individuals with ASD may present hyper or hypo activity to sensory input. ITs allow for customization, easily becoming sensory-friendly items. Moreover, many individuals with ASD are often confused by unpredictability, social nuance, and rapid changes in real-world environments (Mesibov et al., 2005). ITs can be programmed for being much more predictable than humans and does not require social communication and social interaction, which constitutes the major difficulties for individuals with ASD (APA, 2013). Moreover, computational interactions can be repeated as many times as necessary for a person achieving mastery. ITs can break down learning tasks into small steps allowing individuals to learn progressively, positively reinforcing their self-confidence. Furthermore, ITs can provide organised and structured environments as well as routines that (a) are explicit, (b) have clear expectations, and (c) deliver consistent rewards for specific responses, which can highly motivate engagement by allowing individuals to make choices and take control over their learning pace. Last but not least, the content of ITs can be selected according to individuals' cognitive and language abilities as well as interests and preferences, facilitating engagement (Rogers & Dawson, 2010).

4.1 Research in ITs for individuals with ASD

The first studies exploring the impact of the use of ITs in individuals with ASD were published in the early 1970s by Colby, an American psychiatrist who was dedicated to the theory and application of computer science and artificial intelligence to psychiatry (Colby, 1973; Colby & Smith, 1971). These studies reported the positive impact of the use of PCs in the language comprehension abilities of minimally verbal individuals. In the 1980s, research focused more on describing the features of ITs that were advantageous for individuals with ASD rather than exploring its impact on improving specific abilities (Panyan, 1984). Some years later, a ground-breaking report was published by Strickland, Mesibov, and Hogan (1996) in which they used virtual reality (VR) technology to increase the ability of crossing the street of children with ASD and overall improvements were obtained.

In the XXI century, the interest for using ITs with individuals with ASD started to rise resulting in an exponential growth in the number of TMI studies published (Kientz, Goodwin, Hayes, & Abowd, 2014). As described previously, the affinity for ITs that many individuals with ASD tend to show (Hardy, Ogden, Newman, & Cooper, 2002) due to its putative predictability, consistency, limited language and minimal social demands (Moore, McGrath, & Thorpe, 2000; Murray, 1997) may account for this increase. Another reason for this growth might be the fact that technological devices have become more and more affordable and accessible (Ploog, Scharf, Nelson, & Brooks, 2013). Mobile applications (i.e., computer programmes; hereafter referred as to “apps”) for PCs and portables devices such as tablets or smartphones, robots, and speech generating devices (SGDs) are amongst the widest used ITs by individuals with ASD (Kientz et al., 2014).

TMI studies published will not be described or summarised in this chapter given that this issue will be fully addressed in Study 1. Instead, a brief introduction and summary of the types of review studies that have used for evaluating the impact of TMI studies on individuals with ASD is explained hereunder.

4.2 Reviews on TMI studies with individuals with ASD

4.2.1 Brief introduction to the types of literature reviews

Two main types of review studies are commonly found in the scientific literature: *narrative* and *systematic*. Narrative reviews are mainly descriptive, do not involve a systematic search of the literature, and thereby often focus on a subset of studies on a particular topic based on availability or author selection (Uman, 2011). Thus, narrative reviews while informative, can often include elements of selection and evaluation bias. Moreover, their quality highly depends on the author knowledge and expertise on the topic reviewed. Finally, narrative reviews can be confusing at times, especially when similar studies obtain different results and conclusions. Systematic reviews typically involve a detailed and comprehensive plan and search strategy derived a priori, with the aim of reducing bias by identifying, appraising, and synthesizing all relevant studies on a particular topic (Uman, 2011). Often, systematic reviews include a *meta-analysis*, which involves the use of statistical techniques to synthesise the data from a number of studies into a single quantitative estimate or summary effect size (Petticrew & Roberts, 2006; Botella & Gambara, 2002). Effect sizes (e.g., odds ratio, weighted mean differences) measure the strength of the relationship between the intervention and the outcome, thereby providing information on the magnitude of the intervention effect.

4.2.2 Literature reviews on TMI studies with individuals with ASD

There has been such a steady increase in the number of publications on TMI studies with individuals with ASD that also the number of reviews on this topic has exponentially grown. In a systematic electronic search conducted by the researcher on January 2016 in four electronic databases (i.e., PsycINFO, Education Resources Information Center, Web of Science and PubMed), over 70 reviews on TMI studies with individuals with ASD were identified. No systematic data analysis has been performed with these reviews yet, but only the number is certainly informing of the high interest that exist in the research community for evaluating the contribution of ITs to individuals with ASD learning.

Amongst the identified reviews, there were some narrative reviews (e.g., Goodwin, 2008; Parsons & Cobb, 2011) and many systematic reviews (e.g., Fletcher-Watson, 2014; Wass & Porayska-Pomsta, 2014) three of which included meta-analyses (Alzrayer, Banda, & Koul, 2014; Grynszpan, Weiss, Pérez-Díaz, & Gal, 2014; Sansosti, Doolan, Remaklus, Krupko, & Sansosti, 2015). These reviews focused on different participant age range (e.g., children, adolescents), different research designs (i.e., single-subject designs, group designs) and the use of different ITs (i.e., PCs, portable devices), but they generally agreed with the following: (a) TMI can be beneficial for individuals with ASD, but (b) the impact of its use needs to be better evaluated by strengthening the methodological procedures and methods used for drawing adequate conclusions on the effectiveness of the TMI studies.

4.3 Constraints of ITs' lifecycle for research studies

Some of the weaknesses identified in these previous reviews have been the use of small samples and the lack of long-term TMI studies (Fletcher-Watson, 2014). One of the reasons that may significantly account for these flaws is related to the ITs' *lifecycle*, as explained by Herrera (2015) (see Figure 3). The lifecycle of ITs is much shorter than the length of many research studies. For recommending an intervention in ASD, with or without ITs, this needs to have been found effective (a) in a high number of participants, (b) in a high number of studies, and (c) by researchers that are independent to the intervention programme used. Achieving this can take a period of 10 years, period in which the IT may have changed or even disappeared. Time becomes, thereby a big constraint which may difficult the establishment of *evidence-based practices* in the field of TMIs for individuals with ASD.

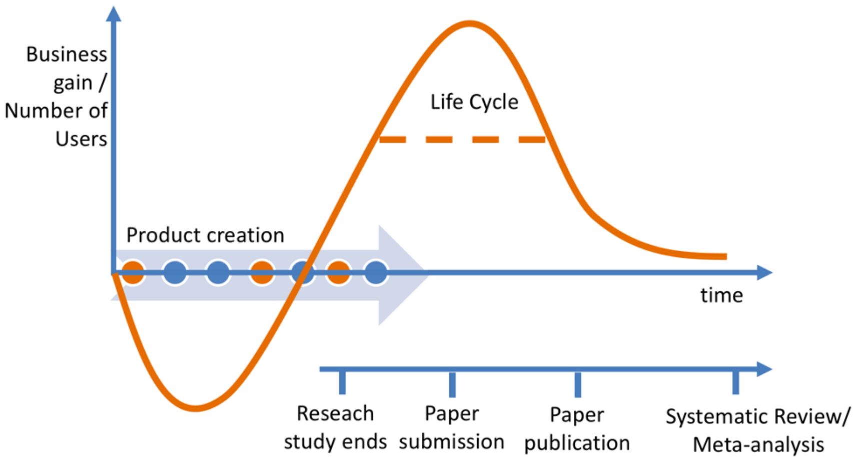


Figure 3. ITs' lifecycle and research studies. Adapted from "App móviles para personas con Trastorno del Espectro del Autismo (Mobile Apps for individuals with Autism Spectrum Disorders)," by G. Herrera, 2015, *Smart Health, 2,* p.25. Copyright 2015 by Smart Health.

5 Evidence-Based Practice

The term *Evidence-Based Practice* (EBP) was first defined in the field of medicine as: "The conscientious, explicit and judicious use of current best evidence in making decisions about the care of the individual patient. It means integrating individual clinical expertise with the best available external clinical evidence from systematic research" (Sackett, Rosenberg, Gray, Haynes, & Richardson, 1996, pp. 71-72). Ten years later, the APA adopted the following Presidential Task Force's proposed definition of Evidence-Based Practice in Psychology (EBPP): "The integration of the best available research with clinical expertise in the context of patient characteristics, culture, and preferences" (Anderson, 2006, p. 273). This, transferred to interventions for individuals with ASD, refers to determining whether a specific programme has been grounded on available evidence and it has used good quality research to gain enough empirical support for adequately concluding about its effectiveness.

6 Research questions

The present thesis addresses the following research questions:

1. Which are the most prominent general trends in state-of-the-art of TMI research with individuals with ASD?
2. Which are the most prominent trends in state-of-the-art of TMI research with individuals with ASD with regard to JA skills?
3. To what degree can existing TMI research on JA skills in the field of ASD be considered EBP?
4. To what extent can the use of a novel IT be effective in improving JA skills in children with ASD?
5. To what extent can a real-world TMI contribute to the promotion of EBP in the ASD field?

The following chapter (i.e., Chapter 2) addresses the first research question with the Study 1 “Enhancing Skills in Individuals with ASD through TMI: a Systematic Review”. Chapter 3 aims the second and third research questions with the Study 2 “Enhancing JA skills in Individuals with ASD through TMI: a Systematic Review and EBP Evaluation”. Finally, Chapter 4 focuses on the fourth and fifth research questions with the Study 3 “Enhancing JA Skills in Children with ASD through an Augmented Reality-TMI”.

Chapter 2

Study 1. Enhancing Skills in Individuals with ASD through TMIs: a Systematic Review

1 Introduction

As explained in Chapter 1, the fast development of ITs and the affinity for ITs that many people with ASD tend to display have contributed to a rise in TMI studies for people with ASD as well as non-systematic reviews (Bellani, Fornasari, Chittaro, & Brambilla, 2011; Buggey & Hoomes, 2011; Goldsmith & LeBlanc, 2004; Goodwin, 2008; Irish, 2013; Parsons & Cobb, 2011; Parsons & Mitchell, 2002; Rayner, Denholm, & Sigafoos, 2009; Scassellati, Admoni, & Mataric, 2012; Shane et al., 2012; Strickland, McAllister, Coles, & Osborne, 2007; Stromer, Kimball, Kinney, & Taylor, 2006) and systematic reviews thereof (Den Brok & Sterkenburg, 2015; Diehl, Schmitt, Villano, & Crowell, 2012; DiGennaro Reed, Hyman, & Hirst, 2011; Fletcher-Watson, 2014; Gardner & Wolfe, 2013; Kagohara et al., 2013; Knight, McKissick, & Saunders, 2013; Lorah, Parnell, Whitby, & Hantula, 2015; Mechling, 2011; Mirenda, 2001; Odom et al., 2015; Pennington, 2010; Ploog et al., 2013; Ramdoss et al., 2012; Ramdoss, Lang et al., 2011; Ramdoss, Mulloy et al., 2011; Shukla-Mehta, Miller, & Callahan, 2010; Stephenson & Limbrick, 2015; Wainer & Ingersoll, 2011; Wass & Porayska-Pomsta, 2014). Moreover, three meta-analytic studies focused on ITs (Alzrayer et al., 2014; Grynszpan et al., 2014; Sansosti et al., 2015) and three other meta-analyses partially included ITs (Bellini & Akullian, 2007; Bellini, Peters, Benner, & Hopf, 2007; Ganz et al., 2012). Finally, some books reviewing ITs for ASD were published recently (Boser, Goodwin, & Wayland, 2014; Cardon, 2016; Ennis-Cole, 2015; Kientz et al., 2014). The continuous growth in the number of TMI studies in ASD underlines the need of periodical reviews to monitor and facilitate progress in this research field.

Although reviews are generally published in academic forums such as journals or books, there are also organizations specifically dedicated to promote and disseminate them. For instance, the Cochrane Collaboration (www.cochrane.org) is a widely recognized and respected international and non-profit organization that promotes, supports, and disseminates systematic reviews and meta-analyses on the efficacy of interventions in the health care field. According to the standards of this organization, systematic reviews should: (a) formulate the review question, (b) define inclusion and exclusion criteria, (c) develop search strategy and locate studies, (d) select studies, (e) extract data, (f) assess study quality, (g) analyse and interpret results, and (h) disseminate findings.

1.1 Terminology

There are terms which are specific to the context of literature reviews such as *primary study(s)* and *primary author(s)*. Primary study(s) refers to each study that has been included in a review, whereas primary author(s) refers to the author(s) of each primary study. Data analysis possibilities within each systematic review highly depend on the research design that was applied in the primary studies. There are mainly two types of research designs: single-subject designs (SSDs) and group designs. SSDs are applied to each individual that is included in the study, thereby each subject serves as his/her own control and the dependent measures are interpreted individually. Group designs are applied to one or more groups of participants, thereby the dependent measures represent all the participants that belong to the same group. When a group design study includes a minimum of two groups and participants are randomly assigned to the groups, this is a *randomised controlled trial* (RCT).

1.2 Key features of TMI studies

Some of the important features evaluated by reviews on TMI studies thus far are (a) participant characteristics, (b) technology item(s) used, (c) target skill(s) addressed, (d) research design, (e) the setting, (f) the country where the study was carried out, (g) the year in which the study was published, and (h) the journal in which the study was published.

Participant characteristics. Most studies included small numbers of participants and predominantly primary aged male children (DiGennaro Reed et al., 2011; Knight et al., 2013; Pennington, 2010; Ramdoss, Lang et al., 2011).

Further, no clear trends have been identified for the ASD diagnosis (e.g., autism, AS, and PDD-NOS) of the individuals who participated in TMI studies.

Technology item(s). In the context of ASD, PCs, portable electronic devices (e.g., SGDs, tablets, and smartphones) and robots are among the most widely used (Diehl et al., 2012; Ganz et al., 2012; Kagohara et al., 2013; Mechling, 2011; Ramdoss et al., 2012).

Target skill(s). Social skills (DiGennaro Reed et al., 2011), social communication and language skills (Ploog et al., 2013), communication skills (Ramdoss, Lang et al., 2011), social and emotional skills (Ramdoss et al., 2012), social communication (Shukla-Mehta et al., 2010; Wainer & Ingersoll, 2011) and academic skills (Knight et al., 2013; Pennington, 2010; Ramdoss, Mulloy et al., 2011) have been the main target skills addressed.

Research design. Several reviews have highlighted a lack of methodological rigour when designing and conducting TMI studies (Knight et al., 2013; Pennington, 2010), and SSDs appear to be the preferred research design for evaluating the effectiveness of TMI effects (Alzrayer et al., 2014; Sansosti et al., 2015).

Setting. Some studies found that the majority of interventions in ASD were conducted in laboratories and clinics (Kasari & Smith, 2013; Parsons & Kasari, 2013). However, reviews that focused on TMI studies found that most of them were carried out in schools (e.g., Pennington, 2010). Sansosti et al. (2015) focused on school-based interventions for their meta-analysis and they included a total of 28 studies.

Country. Although most reviews have not explicitly included *country* as a feature of interest, this is described in many primary studies and might be a significant feature for consideration in TMI studies. Although ASD affects individuals regardless of race, ethnicity or country of origin (Fombonne, 2009), the vast majority of ASD studies have been conducted in English-speaking high-income countries (e.g., US, UK and Australia).

Year. Previous reviews have found that the number of studies on the use of ITs with individuals with ASD have significantly increased since the beginning of the XXI century and that this number has presented an exponential growth especially in the last few years (Fletcher-Watson, 2014; Grynszpan et al., 2014; Kientz et al., 2014).

Journal. There is some debate as to the type of journals publishing the most TMI studies. One review by Mirenda (2001) indicated that most of the research on technology and ASD has been published in speech-language pathology/communication, education, and ABA journals. However, Fletcher-Watson (2014) argued that most of the papers published may not be read by psychologists, educators or other scholars with a primary interest in ASD, because –as a result of interdisciplinary computer-assisted learning projects– they tend to be published in computing journals.

1.3 Features as selection criteria in previous review studies

Although the aforementioned features have been considered in some reviews, many have used a particular feature as a selection criterion. For example, there are some reviews which only included studies that have used a specific type of technology item (e.g., Diehl et al., 2012; Ganz et al., 2012; Kagohara et al., 2013; Mechling, 2011) or focused on a specific target skill (DiGennaro Reed et al., 2011; Knight et al., 2013; Pennington, 2010; Ploog et al., 2013; Ramdoss et al., 2012; Ramdoss, Lang et al., 2011; Ramdoss, Mulloy et al., 2011; Shukla-Mehta et al., 2010; Wainer & Ingersoll, 2011). Besides, some researchers only included children (e.g., DiGennaro Reed et al., 2011; Shukla-Mehta et al., 2010; Stromer et al., 2006) or considered only studies using a specific research design (e.g., Ganz et al., 2012; Grynszpan et al., 2014). Finally, the principal aim of many reviews has been to analyse the results provided by the primary studies to conclude whether the TMI studies were effective or not (e.g., Wass & Porayska-Pomsta, 2014).

1.4 Scope of this review

To the researcher’s knowledge, no review thus far has analysed all of these features together to obtain a broader and in-depth description of the characteristics of TMI studies by (a) involving the whole age range, (b) including all types of ITs used and (c) addressing all target skills that research has identified to be important for the development, education and wellbeing of individuals with ASD. The purpose of this review is to analyse the aforementioned features with the principal aim of describing the current research trends in TMI studies for individuals with ASD. Its main contribution is to give an overview of the characteristics of TMI studies which have been recently researched in order to shape the way forward in the use of ITs not only in research, but also in teaching and care for individuals with ASD.

2 Method

2.1 Search procedure

A systematic search was conducted of four electronic databases: (a) PsycINFO, (b) Education Resources Information Center (ERIC), (c) PubMed, and (d) Web of Science (WoS). The terms *Autis**, *Autism Spectrum Disorder/ASD*, *Autism Spectrum Condition/ASC*, *Asperger Syndrome*, *Pervasive Developmental Disorder/Pervasive Developmental Disorder Not-Otherwise Specified/PDD** and *Technolog**, *Technology Enhanced Learning/TEL*, *Computer**, *Computer Assisted Technology/CAT*, *Virtual**, and *Robot** were used as keywords to identify papers written in English and published in peer-reviewed journals during 2000-2015. The search was conducted to include title and abstract (see formulas in Appendix A) in two different time points: a first search was led in January 2015 to identify papers published between 2000 and 2014, and a second search was led in January 2016 to identify papers published in 2015. Hand searches were also conducted across the references in the identified papers at both times.

2.2 Inclusion and exclusion criteria

In order to be included in this review, each paper had to contain at least one empirical study that meets the following inclusion criteria:

- Examined the effectiveness of a TMI.
- Defined TMI as any intervention that (a) was implemented for a minimum of two sessions and (b) used at least one piece of technology as an independent variable.
- Considered a TMI that was implemented for at least one participant with an ASD diagnosis (i.e., ASD, childhood autism, atypical autism, autistic disorder, Asperger's disorder, AS, PDD-NOS, and PDD unspecified).
- Focused on the improvement of any skill related to (a) the symptoms of ASD (as described in Chapter 1); (b) a specific area of the curriculum; and (c) any other ability that is important for the wellbeing of the individual. The target skill was the dependent variable of the study.

As a result, studies based upon the following criteria were excluded from this review:

- Any type of review.
- Papers where the piece of technology was only used as an assessment tool.
- Papers that assessed an individual's attitudes, preferences and reactions towards an item of technology.
- Technology usability studies carried out for the evaluation of an item's potential, the feasibility of a new approach or the validation of a specific system.
- Papers whose authors claimed the use of technology but used low technology (e.g., a paper-based book with pictures and three-dimensional objects) instead of medium/high technology (e.g., electronic devices).

- Studies where the intervention was implemented for practitioners, parents or carers instead of being implemented directly for the individuals with ASD (e.g., teleconferencing, telepractice).
- Studies that did not provide information for more than two of the features that were considered for the analysis of this review (see the features on p. 106).

When a paper included more than one intervention, only the ones that matched the inclusion criteria were considered (see for example Sitdhisanguan, Chotikakamthorn, Dechaboon, & Out, 2012; Tjus, Heimann, & Nelson, 2004). In the studies that included both individuals with ASD and individuals with a different diagnosis, then only participants with ASD were considered (see for example Yakubova & Taber-Doughty, 2013).

2.3 Study selection procedure and inter-observer agreement (IOA)

In the first search that was run to identify papers published in the time period 2000-2014, the study selection task was conducted by the researcher with the help of two colleagues: one PhD candidate and one postdoctoral researcher, both with expertise in the field of ASD. For the initial stage, a list containing all of the papers –excluding duplications– that emerged from the search strategy described above was created using the online bibliographic management program RefWorks. Titles and abstracts from this initial list of papers were examined. The papers that were not related to the topic (e.g., studies with medical or neurophysiological focus) were excluded. The first stage of the selection resulted in a list of 513 papers. In order to ensure the accuracy of the systematic search, in the next stage the researcher and the PhD candidate independently reviewed the 513 full-text papers and further applied the aforementioned inclusion and exclusion criteria. Subsequently, the postdoctoral researcher checked the papers that the previous two had agreed upon. This yielded a 100% IOA for a final list of 139 papers. Next, the researcher and the PhD candidate independently searched the content of these 139 papers to extract information corresponding to the following features:

- Characteristics of participants involved in the study (i.e., number, gender, age and diagnosis)
- The technology used as an independent variable
- The target skill measured as a dependent variable
- Research design applied in the study
- Setting where the intervention was implemented
- Country where the study was conducted
- Year in which the paper was published
- Journal in which the paper was published

They independently completed two templates and the postdoctoral researcher checked them (IOA = 98.7%). The postdoctoral researcher went through the papers in which the differences between observers were found to identify the reasons for these discrepancies. The three researchers then discussed the discrepancies until a 100% agreement was reached.

In the second search that was run to identify papers published in 2015 and to update the review, the study selection and information extraction tasks were conducted by the researcher following the same procedures as in the first search. After deleting duplications identified across the two searches (i.e., papers that were previously published online and were finally placed in journal volumes published in 2015), and adding the hand-searched papers, the very final list consisted of 178 papers (see Appendix B for finding the information extracted from the reviewed studies; see Appendix C for finding the list of references of the reviewed studies). The papers of Bhattacharya, Gelsomini, Pérez-Fuster, Abowd, and Rozga (2015), Costa, Santos, Soares, Ferreira, and Moreira (2010), and Saiano, Garbarino, Lumachi, Solari, and Sanguineti (2015) were published in conference proceedings instead of journals. However, as these publications are full-length papers and they were peer-reviewed, they have been included in this review as well. The study selection procedure is depicted in Figure 4.

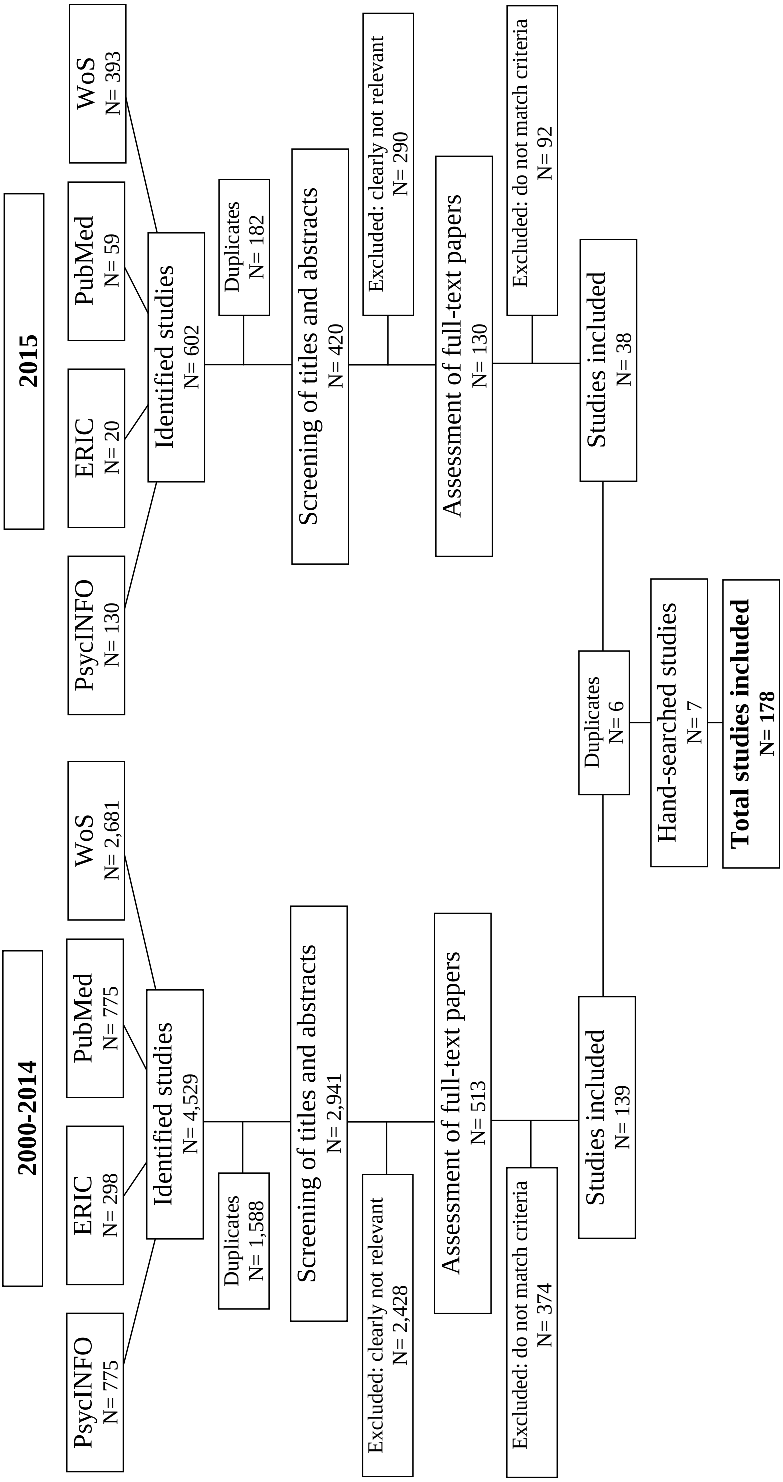


Figure 4. Flow diagram of study selection.

2.4 Data analysis

Univariate and bivariate analyses were conducted using IBM SPSS Statistics 22.0 with the data obtained on the features mentioned previously. Eight of the 178 papers included two studies. Each of the studies in these eight papers reported the same information for all the features with the exemption of number and gender of participants, and research design. Therefore, most features were analysed for 178 papers and only number and gender of participants, and research design were analysed for 186 studies.

3 Results

The groups, categories and subcategories that are used to classify the information that has been extracted for each feature (e.g., age groups and target skills categories) have been created *ad hoc* for this review.

3.1 Univariate analyses

Since each feature has been analysed separately for this type of analysis, results are presented in different sections, one for each feature.

3.1.1 Participant characteristics

Number. The total number of people with ASD who were included in the 186 studies is 1,850. It is worth mentioning that 25 studies (13%) included only one participant, and 146 studies (78%) employed less than 10 participants. Only 16 studies (9%) included more than 30 participants and the study with most participants was that of De Vries, Prins, Schmand, & Geurts (2015) (i.e., 121 participants).

Gender. Of the 1,850 participants, 1,317 were males (71%), 239 were females (13%), and there was no gender description for 294 participants (16%) as 13 studies (7%) did not provide this information. If only studies with data on the gender are considered for the analysis, of the 1,556 participants, 85% were males and 15% were females. In other words, there were more than five times as many males as females included in the studies. Of the 173 studies that reported participant gender, 87 included only males (50%), five included only females (3%) and 81 included both males and females (47%).

Age. Participants were classified into the following age groups: (a) early years (i.e., 2-4 years old); (b) primary (i.e., 5-11 years old); (c) secondary (i.e., 12-17 years old); and (d) post-secondary (i.e., 18+ years old). Since 18 is the usual age individuals finish school across the world, this was selected as a cut-off point to define the fourth age group. Of the 178 reviewed papers, eight did not provide the age of the participants (4%). Participants ranged from 2 to 60 years old. Children of primary school age were involved in 112 papers (66%), 55 of which (32%) exclusively considered participants of this age. Early-year participants were included in 28 papers (16%). Secondary participants were considered in 74 papers (44%). Post-secondary participants were included in 29 papers (17%). Only 16 papers (9%) fully focused on post-secondary participants.

Diagnosis. According to the diagnostic labels provided by the primary authors, the reviewed papers have included individuals with: (a) PDD; (b) autism; (c) AS; (d) PDD-NOS; (e) ASD; (f) Autism Spectrum Condition (ASC); (g) mild autism; (h) moderate autism; (i) severe autism; (j) low-functioning autism (LFA); and (k) high-functioning autism (HFA). Fifty-six papers (32%) included individuals with a diagnosis of ASD. Fifty-one papers (29%) involved individuals with a diagnosis of autism. Participants diagnosed with AS were considered in 26 papers (15%). Forty-one papers (23%) included participants with different diagnoses (e.g., six papers included participants with autism and participants with PDD-NOS). Mild autism, HFA and AS might be diagnoses that describe participants with higher cognitive and verbal language abilities; 22 papers (12%) focused on participants that have one of these diagnoses.

3.1.2 Technology

Three categories of technology have been examined: (a) hardware (HW); (b) software (SW); and (c) medium of delivery (MoD). HW has been defined as the main piece of technology that was used in the intervention; SW refers to the type of program that was run in the piece of technology to deliver the intervention; and MoD expresses how the piece of technology was used for delivering the intervention. Different subcategories of HW, SW and MoD have been identified across the papers included in this review. Each subcategory has been named and described with the support of a senior researcher colleague who is an expert in technology development and technology use by individuals with ASD. HW, SW and MoD subcategories names with their corresponding descriptions and the number, and percentage, of papers in which one of them was used are presented in Tables 1-3.

HW. According to the data collected, PC is the most extensively used HW (95 papers, 53%) followed by tablets (29 papers, 16%) and smartphone/small handheld devices (17 papers, 10%). There are eight papers (5%) that used a combination of HW: three used a PC and a tablet, two used a tablet and a smartphone/small handheld device, two used a PC and a smartphone/small handheld device, and one study used a PC and a robot. Considering this, the number of papers that used a PC as one of the HW is 101 (57%).

SW. Generic SW was used in 68 papers (38%), special needs SW in 52 papers (29%) and research SW in 51 papers (29%).

MoD. Interactive sequence was clearly the most used method for delivering the intervention (55 papers, 31%). This is followed by prompting methods (35 papers, 20%). It has been found that 17 papers (10%) used a combination of different subcategories of MoD: eight used prompting and interactive sequence, three used interactive agent and simulation, two papers used interactive sequence and interactive agent, another two used prompting and augmented information, one

Table 1. Description of the subcategories of HW and number (*N*) and percentage (%) of papers that used each HW.

HW	Description	Papers	
		N	**%**
Personal computer (PC)	Any laptop or desktop PC with any operative system (OS) (e.g., Microsoft Windows OS, Apple OS X, Linux). It can be accompanied by the use of a range of computer input peripheral devices (e.g., keyboard, mouse, touchscreen, joystick, gamepad, video camera, microphone, eye tracking system and motion sensing input device), and computer output peripheral devices (e.g., monitor, projector, TV screen, virtual glasses, speakers and headphones).	95	53%
Tablet	Any tablet computer with any OS (e.g., Google Android, Apple iOS, Microsoft Windows). It can be accompanied by the use of accessories such as keyboard and digitized pen.	29	16%
Smartphone/ small handheld device	Any smartphone with any OS (e.g., Google Android, Apple iOS, Microsoft Windows). Also Personal Digital Assistants (PDAs) and advanced MP4 devices of any trademark.	17	10%
Robot	Any robot of any appearance (i.e., humanoid and non-humanoid). It can be accompanied by the use of additional items, which can be embedded on the robot or be peripheral, such as video camera, microphone, eye tracking system and motion sensing input device.	15	8%
Combination	More than one subcategory of HW is used in the same study.	8	5%
Conventional player	Any electronic device that is used for playing audio and video files presented in a variety of other HW (e.g., VHS, CD, DVD, Blu-Ray Disc). It is often accompanied by the use of a TV screen.	7	4%
Interactive digital whiteboard (IDW)	Any IDW, which is accompanied by a PC and a projector.	3	2%
Speech generating device (SGD)	A device that is specifically used as an electronic AAC system for individuals to verbally communicate.	2	1%
Video game console	Any type of home video game console and handheld video game console (i.e., smaller and portable). Home video game console is often accompanied by the use of a TV screen and a gamepad.	2	1%
Total		178	100%

Table 2. Description of the subcategories of SW and number (*N*) and percentage (%) of papers that used each SW.

SW	Description	Papers	
		N	**%**
Generic	Any type of commercially available SW (including free SW) to be used by general population (e.g., text processors, video players, slide show SW).	68	38%
Special needs	Any type of SW that has been specially designed for individuals with special needs (e.g., ASD-specific educational SW) that is currently commercially available or it has been available in the past (it includes free SW).	52	29%
Research	Any type of SW that has been developed for the purpose of the study and it has not been commercialized anyhow, at least, not at the time the study was carried out.	51	29%
None	No SW is used (e.g., a conventional player that is used with video tapes).	7	4%
Total		178	100%

paper used prompting and simulation, and another one used interactive sequence, interactive agent and simulation. Thus, the number of papers that used interactive sequence rises to 66 (37%), and the number of papers that used prompting becomes 46 (26%).

A part from the analyses of HW, SW and MoD, it has been found that 134 papers (75%) implemented the TMI with no comparison condition; 39 papers (22%) compared the use of technology to a traditional method (e.g., a tablet vs. paper-based cards); and only five papers (3%) compared the use of an IT to the use of another IT (e.g., a PC vs. a tablet).

Table 3. Description of the subcategories of MoD and number (*N*) and percentage (%) of papers that used each MoD.

MoD	Description	Papers	
		N	**%**
Interactive sequence	SW is used by the participant to view/listen/interact with sequences of visual/auditory items or to play with games, for practising a target skill (e.g., digital stories, problem solving tasks).	55	31%
Prompting	SW is used to deliver prompts for the participant (e.g., to do a task, to engage with an activity) through video modelling, video/picture/text instruction or video feedback.	35	20%
Interactive agent	Virtual characters, avatars, robots or real persons recorded in video segments to provide initiations and responses according to participant's actions.	22	12%
Simulation	SW shows virtual environments (2D/3D) that simulate real-life situations for the participant to navigate through.	21	12%
Sentence composition and speech generation	SW is used by the participant to compose a sentence from a catalogue of words or pictures so that the sentence is read and/or presented visually by the SW.	21	12%
Combination	More than one subcategory of MoD is used in the same study.	17	10%
Augmented information	SW is used to facilitate the participant by providing visually augmented information (e.g., schedules, timers) and sensor-based augmented information (e.g., reinforcers after detecting user actions).	4	2%
Collaborative games	SW that is used for two or more participants to interact with each other.	3	2%
Total		178	100%

3.1.3 Target skills

The range of skills identified in the review have been classified in three categories: (a) social communication and social interaction skills, (b) academic skills and (c) life skills (see Table 4). The first category includes skills related to the social communication and social interaction of the participant; the second category includes skills that belong to the participant's academic curriculum; and the third category includes skills related to the wellbeing and social and labour market inclusion of the participant. The number and percentage of papers that have targeted each category are shown in Figure 5.

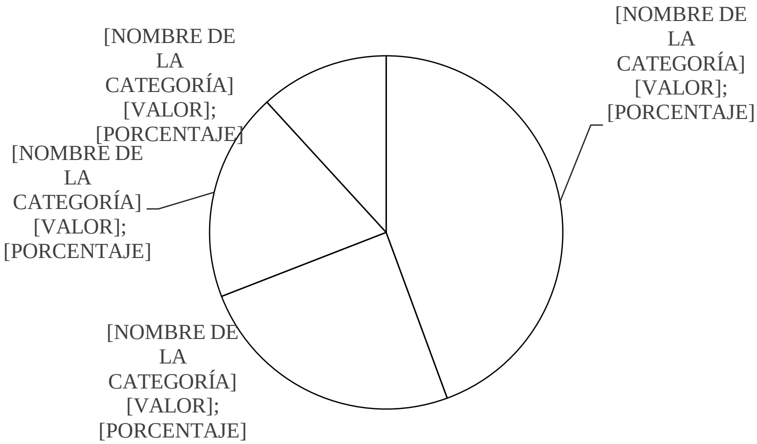


Figure 5. Number and percentage of papers that targeted each category of the feature target skills.

It is important to highlight that the category assigned to each study has been based on the context in which the skill was practised. For instance, in Weng & Bouck's (2014) study participants practised mathematics for learning about price comparison. Since the final aim of the study was to help participants in money management, the category assigned to this study has not been academic skills but life skills. Another example is the study of Strickland, Coles, & Southern (2013), in which participants practised social communication and social interaction skills for improving job interview skills; the category assigned to this study has been life skills.

The vast majority of the papers (157 papers, 88%) targeted skills from a particular category. Half of these papers (79 papers, 44%) explored interventions with a focus on social communication and social interaction.

Table 4. Range of skills identified in the reviewed papers for the three categories of the feature target skills.

Category	Descriptors
Social communication and social interaction skills	• Verbal communication (e.g., speech production, prosody) • Non-verbal communication (e.g., imitation, eye contact, pointing, joint attention) • Social interaction, social collaboration and social conversation (e.g., greeting, complimenting, turn-taking) • Social engagement and social competence • Initiating, making requests • Responding to others' behaviours • Social problem-solving strategies • Developing and maintaining relationships • ToM components (mentalising): belief, intention, deception, emotion, imagination and pretending • Perspective taking skills • Understanding of empathy • Play, collaborative play, imitative play • Imaginative play, pretend play • Recognition (including face processing), understanding, expression and regulation of emotions
Academic skills	• Literacy (e.g., alphabet, vocabulary, grammar, writing, orthography, spelling, reading and text comprehension) • Numeracy (e.g., mathematics, calculation) • Picture recognition, identification and naming • Fine motor skills (e.g., calligraphy) • Subjects' content: science, nature • Body scheme, body awareness • Shape and colour recognition and classification • Task engagement (e.g., being sit, looking at the materials, being focused on the activity) • Executive function, reasoning, cognitive processing and cognitive flexibility: attention, perception, working memory
Life skills	• Independence: reducing number of prompts/supports by others • Transitioning • Time, waiting-situations management • Functional use of objects • Daily living activities (e.g., setting a table, cooking, doing laundry, shopping) • Seeking employment, practicing job interview skills, work performance (e.g., sorting mail) • Money management • Leisure skills (e.g., photography) • Physical exercise, fitness • Fine and gross motor skills (e.g., body movements) • Sensory motor coordination • Safety skills (e.g., street crossing, fire, tornado) • Reducing anxiety, phobia, fear • Reducing stereotyped/repetitive behaviour • Reducing challenging behaviour (e.g., self-injury, tantrums)

Twenty-one papers (12%) focused on more than one target skill: eight targeted social communication and social interaction, and academic skills; seven papers focused on social communication and social interaction, and life skills; five papers aimed at academic and life skills; and the paper of Whalen et al. (2010) targeted a variety of skills from all the three categories. Considering this, the number of papers that focused, at least partially, on social communication and social interaction skills is 95 (53%).

3.1.4 Research design

The 186 reviewed studies have been classified according to the research design that authors of the studies used for evaluating the effectiveness of the intervention. SSDs and group designs have been defined in the introduction of this study (see p. 100). Types of SSD and group design that have been identified in the reviewed studies are presented and described in Table 5 and Table 6, respectively. The number and percentage of studies that used each type of research design are shown in Table 7. It is worth mentioning that the type of research design that has been assigned to each study is the one indicated by the primary authors in the method section of the reviewed papers.

Most of the reviewed studies have applied SSDs (134 studies, 72%); multiple baseline and multiple probe are the preferred types, representing together the 54% of the studies that have used SSD. Nine studies (7%) have applied a combination of SSD: four studies used multiple probe and alternating treatment designs, three studies used multiple baseline and alternating treatment designs, another study applied multiple probe and reversal designs, and another one used multiple baseline and reversal designs. Considering this, the percentage of SSD studies that applied either multiple baseline or multiple probe designs, exclusively or in combination with other designs, rises to 60%.

Regarding the group designs, the number of studies that included control group was equal to the number of studies that did not include control group (i.e., 26 studies). In eight (31%) of the studies that included control group, participants were not randomly assigned to the groups.

Table 5. Description of the types of SSD identified in the reviewed studies.

SSD	Description	
	Function	**Effectiveness evaluation**
AB	This is a two-phase design consisting of a no-intervention baseline phase (A) and an intervention phase (B). The existence of a no-intervention baseline allows for the establishment of a relationship between intervention and outcome.	If a significant change in the dependent measure occurs at the onset of the intervention phase (B), the researcher may infer that the intervention is effective.
Reversal	The simplest reversal design is the ABA design, which is a three-phase design consisting of a no-intervention baseline phase (A), an intervention phase (B), and a no-intervention withdrawal phase (A'). The existence of a no-intervention baseline and withdrawal phases allows for a more reliable establishment of a relationship between intervention and outcome than in the AB design.	If a significant change in the dependent variable occurs at the onset of the intervention phase (B) and it is reversed at its offset (A'), the researcher may infer that the intervention is effective. For increasing reliability, more intervention and no-intervention withdrawal phases can be considered: ABAB, ABABA, etc.
Multiple baseline	This design allows for evaluation across participants, activities and settings. An AB design across participants is one example in which participants start the intervention phase at different time points (i.e., no-intervention baseline phase (A) has different duration for each participant).	If a significant change in the dependent measure occurs at the onset of the intervention phase (B) for all participants, the researcher may infer that the intervention is effective. For increasing reliability, more intervention and no-intervention withdrawal phases as well as follow-up measures (e.g., one month after the intervention) can be considered.
Multiple probe	In this design, which is considered to be an adaptation of the multiple baseline design, multiple probes (i.e., sessions in which data is collected) are registered at the same time points across participants, activities or settings. Intervention phases are introduced at different time points for each participant, activity or setting, while no data is collected from the others.	If a significant change in the dependent measure occurs at the onset of the intervention phase and it is maintained in the after-intervention probes for all participants, the researcher may infer that the intervention is effective.
Alternating treatment	It is also known as *simultaneous treatment design* or *multi-element design* and it allows for comparing the effectiveness of different interventions on the same dependent variable. A baseline phase can be considered and the implementation of the interventions can be counterbalanced across or within sessions.	If a significant change in the dependent measure occurs at the onset of one of the interventions compared to the other one/s, the researcher may infer that the former intervention is more effective than the later one/s.
Exploratory	Researchers do not apply any specific research design because the data collection process and the analysis method are not defined a priori.	

Table 6. Description of the types of group design identified in the reviewed studies.

Group design	Description	
	Function	**Effectiveness evaluation**
Without control group	One or more groups of participants who receive the intervention are used.	If a significant change is observed when comparing the dependent measures before and after the intervention, the researcher may infer that the intervention is effective.
With control group	A minimum of two groups are used: the experimental group (i.e., participants who receive the intervention) and the control group, in which participants either do not receive the intervention or receive the intervention after the intervention group (i.e., waitlist control group). If participants are randomly assigned to the groups, the design is named **randomised controlled trial (RCT)**.	If a significant change is observed when comparing the dependent measure of the experimental group before and after the intervention and no change is observed for the control group, the researcher may infer, with more reliability than in a design without control group, that the intervention is effective.

Table 7. Number and percentage of studies that used each type of research design.

SSD	Multiple baseline		37	28%	
	Multiple probe		35	26%	
	Alternating treatment		20	15%	
	AB		16	12%	
	Reversal		10	7%	
	Combination		9	7%	
	Exploratory		7	5%	
				100%	
	(SSD total)		134		72%
Group design	With control group	Randomised	18		
		Not randomised	8		
			26	50%	
	Without control group		26	50%	
				100%	
	(Group design total)		52		28%
	Total				100%

3.1.5 Setting

Interventions have been classified in two groups according to whether they were implemented in real-world settings or laboratory settings. Real-world setting is defined as a place that is not new for the participant; s/he is familiar with the place because s/he spends time in it on a regular basis. Places that have been identified in the review and have been considered to be real-world settings are: home, school, after school centre, community, parents' office, therapy centre (also therapy room and clinic), day centre (also day treatment centre), residential care facility, vocational centre and work place. Laboratory setting is defined as a place that is new for the participant; s/he goes to this place for first time to receive the intervention. Laboratories located in research centres or universities are the sceneries that have been identified in the review and considered to be laboratory settings.

Most of the interventions have been wholly implemented in real-world settings (146 papers, 82%), especially in schools (92 papers, 52%), therapy centres (20 papers, 11%) and homes (10 papers, 6%). There were 20 papers (11%) that had a combination of settings because the interventions were implemented in different settings for each participant; the most frequent combination was school and home (seven papers, 4%). Considering this, the numbers of papers with interventions that have been, at least partially, implemented in schools and homes are 106 (60%) and 22 (12%), respectively. These two settings together (128 papers) represent the 88% of the papers which described studies that were conducted in real-world settings, and the 72% of the total reviewed papers. Five papers (5%) included a combination of a real-world setting with a laboratory setting. Fourteen papers (8%) did not provide information on the setting where the intervention was implemented.

3.1.6 Country

The studies included in this review took place in 22 different countries (see Table 8). A high number of studies (107 papers, 60%) were developed in the United States (US). If all the studies conducted in English-speaking high-income countries (i.e., Australia, Canada, Ireland, UK, US and New Zealand) are added together (138 papers), they represent 78% of the papers which were reviewed. From another perspective, 64% of the studies (114 papers) were conducted in America, 17% in Europe (31 papers), 10% in Asia (18 papers), and 7% in Australia and Oceania (13 papers). Some primary studies did not mention the country where the study was conducted. In the cases in which all of the authors' affiliations belonged to the same country, that country was assigned to the study. In cases in which the authors' affiliations belonged to different countries, no country could be assigned to the study. Finally, two papers (1%) did not provide the country where the study took place.

Table 8. Number (*N*) and percentage (%) of the reviewed papers according to the country.

	Country	**Papers**	
		N	**%**
1	US	107	60%
2	UK	11	6%
3	New Zealand	7	4%
4	Taiwan	7	4%
5	Australia	6	3%
6	Canada	6	3%
7	The Netherlands	6	3%
8	Israel	4	2%
9	Italy	3	2%
10	Japan	3	2%
11	Romania	3	2%
12	Spain	3	2%
13	Brazil	1	1%
14	France	1	1%
15	Germany	1	1%
16	Ireland	1	1%
17	Korea	1	1%
18	Portugal	1	1%
19	Singapore	1	1%
20	Sweden	1	1%
21	Thailand	1	1%
22	Turkey	1	1%
	N/A	2	1%
	Total	178	100%

3.1.7 Year

Between 2000 and 2009, fewer than eight papers were published per year (see Figure 6). This trend changed in 2010 with the publication of 12 papers (7%) in that year. The number kept increasing in 2012, 2013 and 2014 with the publication of 16 (9%), 27 (15%) and 29 (16%) papers, respectively. The figure dramatically rose to 40 papers (23%) in 2015. Thus, 135 papers (76%) were published during 2010-2015, and the number of publications for this period increased by 214% compared to 2000-2009. It is also interesting to note that the number of papers published in 2015 increased by 38% compared to 2014.

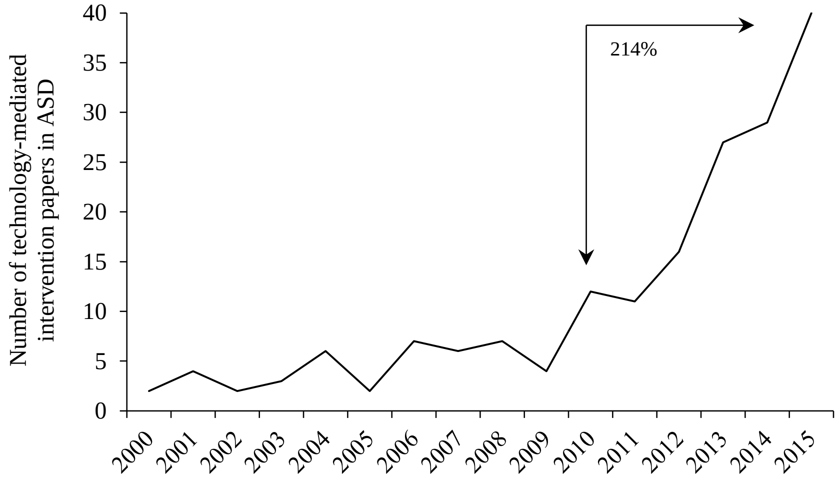


Figure 6. Number of TMI papers in ASD published during 2000-2015.

3.1.8 Journal

The 178 papers were published in 75 different journals (see Table 9), 45 of which are included in the recognized authority for evaluating journals *Journal Citation Reports®* (JCR; Thomson Reuters, 2016).

According to their aim and focus, the journals have been classified into six groups: (a) journals that focus on ASD, other developmental disorders and special needs; (b) journals that focus on psychology, education and other related disciplines (e.g., linguistics); (c) journals that focus on medicine and neuroscience; (d) journals that focus on computer science or technology; (e) journals that have an interdisciplinary focus on computer science or technology and another discipline (e.g., psychology, education); and (f) journals that focus on multiple disciplines.

Table 9. Number (*N*) and percentage (%) of the reviewed papers according to the journal and description of journals' focus and impact factor (IF).

	Journal[a]	Papers		Focus	IF[b]
		N	**%**		
1	Journal of Autism and Developmental Disorders	28	16%	ASD/SN	3.493
2	Research in Autism Spectrum Disorders	16	9%	ASD/SN	1.317
3	Focus on Autism and Other Developmental Disabilities	10	6%	ASD/SN	1.273
4	Autism: The International Journal of Research and Practice	9	5%	ASD/SN	3.170
5	Education and Training in Autism and Developmental Disabilities	9	5%	ASD/SN	
6	Journal of Developmental and Physical Disabilities	7	4%	ASD/SN	0.880
7	Computers & Education	5	3%	Tech & Psy/Edu/Med	2.881
8	Journal of Positive Behavior Interventions	5	3%	Psy/Edu	1.545
9	Research in Developmental Disabilities	5	3%	ASD/SN	1.877
10	Developmental Neurorehabilitation	4	2%	Med/Neurosci	1.578
11	Behavior Modification	3	2%	Psy/Edu	1.219
12	Journal of Child Psychology and Psychiatry	3	2%	Psy/Edu	6.615
13	Research and Practice for Persons with Severe Disabilities	3	2%	ASD/SN	0.738
14	Annual International Conference of the IEEE Engineering in Medicine and Biology Society	2	1%	Tech & Psy/Edu/Med	N/A
15	Assistive Technology	2	1%	Tech & Psy/Edu/Med	1.283
16	Augmentative and Alternative Communication	2	1%	ASD/SN	2.960
17	Child & Family Behavior Therapy	2	1%	Psy/Edu	
18	Clinical Case Studies	2	1%	Psy/Edu	0.359
19	Education & Treatment of Children	2	1%	Psy/Edu	
20	Interaction Studies: Social Behavior and Communication in Biological and Artificial Systems	2	1%	Tech & Psy/Edu/Med	0.535
21	Journal of Special Education Technology	2	1%	Tech & Psy/Edu/Med	
22	Teaching Exceptional Children	2	1%	ASD/SN	
23	ACM Transactions on Accessible Computing	1	1%	Tech & Psy/Edu/Med	
24	Annual Review of CyberTherapy and Telemedicine	1	1%	Tech & Psy/Edu/Med	
25	Assistive Technology Outcomes and Benefits	1	1%	Tech & Psy/Edu/Med	
26	Australasian Journal of Early Childhood	1	1%	Psy/Edu	
27	Autism Research and Treatment	1	1%	ASD/SN	
28	Autonomous Robots	1	1%	Tech	1.547
29	Behavioral Development Bulletin	1	1%	Psy/Edu	
30	Behavioral Interventions	1	1%	Psy/Edu	0.500
31	Clinical Pediatrics	1	1%	Med/Neurosci	0.954
32	Development and Psychopathology	1	1%	ASD/SN	3.646
33	Developmental Neuropsychology	1	1%	Psy/Edu	1.947
34	Educational Sciences: Theory & Practice	1	1%	Psy/Edu	

(*continued*)

Table 9 (*continued*)

	Journal[a]	Papers *N*	Papers %	Focus	IF[b]
35	Expert Systems	1	1%	Tech	0.947
36	IEEE Intelligent Systems	1	1%	Tech	3.532
37	IEEE Transactions on Autonomous Mental Development	1	1%	Tech	1.205
38	Industrial Engineering & Management Systems	1	1%	Tech	
39	Information Sciences	1	1%	Tech	3.364
40	Information, Communication & Society	1	1%	Tech	2.109
41	Intellectual and Developmental Disabilities	1	1%	ASD/SN	
42	International Conference on Interaction Design and Children (IDC, ACM)	1	1%	Tech & Psy/Edu/Med	N/A
43	International Journal of Circumpolar Health	1	1%	Med/Neurosci	0.707
44	International Journal of Developmental Neuroscience	1	1%	Med/Neurosci	2.380
45	International Journal of Social Robotics	1	1%	Tech	1.407
46	International Journal of Special Education	1	1%	ASD/SN	
47	International Journal on Disability and Human Development	1	1%	ASD/SN	
48	Journal of Applied Behavior Analysis	1	1%	Psy/Edu	1.348
49	Journal of Applied Rehabilitation Counseling	1	1%	Med/Neurosci	
50	Journal of Behavioral Education	1	1%	Psy/Edu	
51	Journal of Educational Computing Research	1	1%	Tech & Psy/Edu/Med	0.644
52	Journal of Evidence-Based Psychotherapies	1	1%	Psy/Edu	
53	Journal of Intellectual & Developmental Disability	1	1%	ASD/SN	0.892
54	Journal of Mental Health Research in Intellectual Disabilities	1	1%	ASD/SN	
55	Journal of Neuroengineering and Rehabilitation	1	1%	Med/Neurosci	2.419
56	Journal of Nonverbal Behavior	1	1%	Psy/Edu	1.365
57	Journal of Speech, Language and Hearing Research	1	1%	Psy/Edu	1.526
58	Journal of Vocational Rehabilitation	1	1%	Med/Neurosci	
59	Molecular Autism	1	1%	ASD/SN	4.961
60	OTJR: Occupation, Participation and Health	1	1%	Psy/Edu	0.524
61	Perceptual and Motor Skills	1	1%	Psy/Edu	0.618
62	Personal and Ubiquitous Computing	1	1%	Tech	1.498
63	PloS One	1	1%	Multiple	
64	Pro-Fono: Revista De Atualizacao Cientifica	1	1%	Psy/Edu	
65	Progress in Brain Research	1	1%	Med/Neurosci	5.103
66	Psychology in the Schools	1	1%	Psy/Edu	1.035
67	Remedial and Special Education	1	1%	ASD/SN	2.016
68	Studies in Literature and Language	1	1%	Psy/Edu	
69	Techtrends	1	1%	Tech & Psy/Edu/Med	

(*continued*)

Table 9 (*continued*)

	Journal[a]	Papers		Focus	IF[b]
		N	%		
70	The American Journal of Occupational Therapy	1	1%	Psy/Edu	
71	The Journal of Educational Research	1	1%	Psy/Edu	1.218
72	The Journal of Special Education	1	1%	ASD/SN	1.415
73	The Journal of Speech and Language Pathology – Applied Behavior Analysis	1	1%	Psy/Edu	
74	The Scientific World Journal	1	1%	Multiple	
75	Topics in Language Disorders	1	1%	Psy/Edu	1.098
	Total	178	100%		

Note. SN = special needs; Tech = technology; Psy = psychology; Edu = education; Med = medicine; Neurosci = neuroscience; N/A = not applicable.
[a]It includes the two conference proceedings where the papers of Bhattacharya et al. (2015), Costa et al. (2010), and Saiano et al. (2015) were published. [b]2015 Impact Factor according to the JCR (Thomson Reuters, 2016).

Of the 178 papers, 101 (57%) have been published in ASD and special needs journals, 36 papers (20%) have been published in psychology and educational journals, 19 papers (11%) have been published in interdisciplinary computer science or technology journals, another 11 papers (6%) have been published in medicine or neuroscience journals, nine papers (5%) have been published in computer science or technology journals, and two papers (1%) have been published in multiple discipline journals.

It is worth mentioning that the five journals that have published the highest number of papers specially focus on ASD. The journal that has published the most TMI papers in ASD is the *Journal of Autism and Developmental Disorders* (28 papers, 16%), followed by *Research in Autism Spectrum Disorders* (16 papers, 9%) and *Focus on Autism and Other Developmental Disabilities* (10 papers, 6%).

3.2 Bivariate analyses

All the features have been analysed in pairs using crosstabs to study the relationship in between them. Data analysis did not reveal meaningful relationships for all the pairs of features. Therefore, only the results for the pairs of features which were found to be related are reported here. Results are presented in different sections, one for each pair of features.

3.2.1 Number of participants and research design

The research design selected by the authors of the papers is related to the number of participants they included (see Figure 7); investigations with large numbers of participants applied group designs, whereas studies with a smaller number of participants mostly applied SSDs. However, it is worth mentioning that of the 146 studies (78%) that included less than 10 participants, 13 (9%) applied group designs.

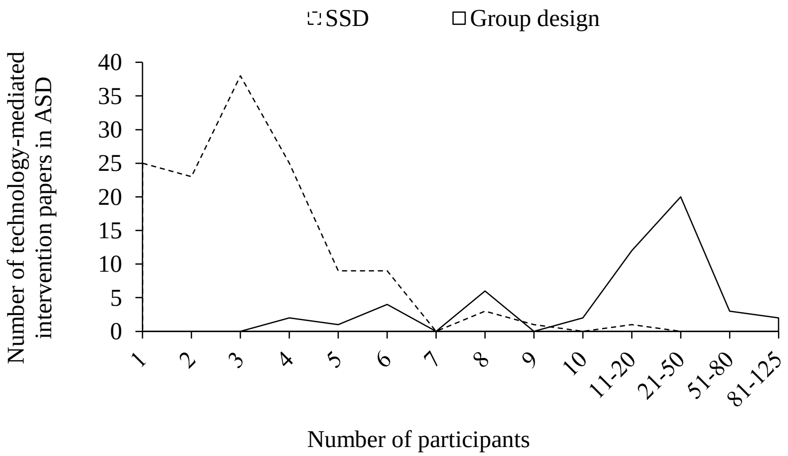


Figure 7. Number of TMI papers in ASD according to the number of participants and research design.

Among the SSD studies, the one with the largest number of participants was that of McEwen (2014), which included 12 participants. Among the group design studies, the ones with the smallest number of participants were that of Saiano et al. (2015) and one of the studies published in Whalen, Liden, Ingersoll, Dallaire, and Liden (2006), which included only four participants each.

3.2.2 Age and target skills

Of the studies that included only children of early years (nine papers) or only primary age children (55 papers), 56% (five and 31 papers in each age group) focused on social communication and social interaction. A total of eight papers (38%) of the studies with secondary age participants only (21 papers) targeted academic skills. Finally, studies that exclusively focused on post-secondary individuals (16 papers) mainly focused on life skills (11 papers, 69%).

3.2.3 Age and setting

Most of the studies that included only primary age participants (38 of 55 papers, 69%) were conducted in schools, and the same holds for the vast majority of the studies that solely included secondary age participants (19 of 21 papers, 91%).

Participants of early and post-secondary years were involved in studies that took place in a very broad range of settings. Studies conducted in vocational centres or work environments only included post-secondary age participants. No studies conducted in therapy centres or clinics included post-secondary individuals.

3.2.4 Technology HW and age

PCs were used with all age groups but especially with primary and secondary age participants; of the 95 papers that used a PC, 79 (83%) included participants of these ages.

Tablets were also used with participants of all ages but mainly with primary age children; of the 29 papers that used tablets, 16 (55%) included children of primary age.

Smartphone/small handheld devices were also used with individuals of all ages but especially with secondary and post-secondary age participants; of the 17 papers that used this HW, 77% (13 papers) included 12-year-olds or older participants.

Of the 15 papers that used robots, only three included participants of secondary age and no paper included participants of post-secondary age.

3.2.5 Technology HW, SW and MoD

PCs were used with the three subcategories of SW described previously: generic SW (35 papers, 37%), research SW (35 papers, 37%), and special needs SW (25 papers, 26%). Tablets were mostly used with special needs SW (17 papers, 59%). Smartphone/small handheld devices were predominantly used with generic SW (10 papers, 59%). Almost all the robot-based studies used research SW (14 papers, 93%). No studies that used a conventional player reported the use of SW. All of the studies that used an IDW or a video game console used generic SW (100%).

With regard to the MoD, PCs were highly used for interactive sequences (43 papers, 45%). Tablets were frequently used as a means for delivering interactive sequences (eight papers, 28%) and sentence composition and speech generation (eight papers, 28%). Smartphone/small handheld devices were mainly used for prompting (11 papers, 65%). Robots were largely used for presenting interactive agents (14 papers, 93%). Conventional player, video game console and SGD were entirely used for prompting, simulation and sentence composition and speech generation, respectively. Of the 21 studies that focused on delivering simulation, 91% (19 papers) used PCs.

3.2.6 Technology HW, MoD and target skills

Most subcategories of HW were mainly used for enhancing social communication and social interaction skills. Only smartphone/small handheld devices were used in a larger number of studies for enhancing life skills (eight papers, 47%).

Similarly, most subcategories of MoD were used to enhance social communication and social interaction. However, interactive sequence was used in a higher number of studies for enhancing academic skills (26 papers, 47%), and prompting was mainly used for increasing life skills (19 papers, 54%).

3.2.7 Technology HW, MoD and setting

Most subcategories of HW were primarily used in schools. Only robots were also highly used in therapy centres or clinics (four papers, 27%). PCs were used in 55% (51 papers) of the studies conducted in schools, in 80% (eight papers) of the studies conducted in homes, in 86% (six papers) of the studies conducted in research centres, and in 67% (four papers) of the studies conducted in laboratories. Two of the three studies that were conducted in vocational centres or work settings used smartphone/small handheld devices (67%).

Most subcategories of MoD were mainly used in schools, especially collaborative games; all of the studies that used this MoD were conducted in schools. Half of the studies that were conducted in homes used interactive sequences (five papers, 50%), and half of the studies that were conducted in laboratories used interactive agents (three papers, 50%). Two of the three studies that were conducted in vocational or work settings used the technology for prompting (67%).

3.2.8 Technology HW, MoD and year

PC is the only subcategory of HW that has been used from 2000 to 2015; its use has been gradually increased along the years up to a point in which 45% of the studies (43 papers) that exclusively used PCs to deliver the interventions were published during 2013-2015. Tablets were not used until 2012 and 72% of the studies that used this HW were published in 2014 and 2015. Smartphone/small handheld devices were firstly used in 2009 and their use present an irregular trend until 2015, with 2010 and 2012 being the years with most publications with this HW (four papers each year, 24%). Robots were used for the first time in 2007 and their use since then has also been irregular, with 2015 being the year in which more papers (five, 33%) with this HW were published. SGDs were used in papers that were published in 2004 and 2007; since then, no studies have used this subcategory of HW. Conventional players, IDWs and video game consoles were used in different years with no remarkable trend; they have been still of use in the last years reviewed.

Interactive sequence is the only subcategory of MoD that has been used throughout 2000-2015. Prompting was used for the first time in 2001, interactive agent for the first time in 2003, sentence composition and speech generation for the first time in 2004, and simulation for the first time in 2005. Augmented information was firstly used in 2009, and collaborative games appeared for first time in a paper that was published in 2013. During 2014-2015, all subcategories of MoD were used.

3.2.9 Target skills and setting

All the identified skills were mostly targeted in studies that were fully conducted in schools. Academic skills were principally targeted in this setting (34 papers, 77%). Seven (70%) of the ten studies that were conducted in home settings focused on social communication and social interaction skills, whereas no home study focused on life skills. Studies entirely conducted in day centres or clinics highly focused on life skills (three papers, 75%) while no day centre study fully focused on academic skills. Studies developed in vocational centres or work settings mainly focused on life skills (two papers, 67%). Five of the seven studies that were conducted in research centres, and five of the six studies that were conducted in laboratories focused on social communication and social interaction skills (71% and 83%, respectively).

3.2.10 Target skills and year

The number of studies focusing on the three target skill categories (i.e., social communication and social interaction skills, academic skills, and life skills) has increased along the years. However, it is worth noting that the first paper that fully focused on life skills was not published until 2006.

3.2.11 Research design and year

Although no general trend was found with regard to the use of different types of research designs over time, 72% of the RCTs (13 papers) were published between 2013-2015.

4 Discussion

4.1 Univariate results

4.1.1 Participant characteristics

Number. An important number of studies included only one participant. This finding could be explained by several factors. One of these factors is related to the inherent heterogeneity that is present in the people who have a diagnosis of ASD: they differ amongst others in symptoms, severity levels, intellectual and language abilities (Boucher, 2009; Jordan, 1999). This heterogeneity might be seen by many as a pretext to look for a specific intervention for each person with ASD. A second factor that might contribute to the phenomenon that many studies include a single participant or only a few participants is the constraint that researchers frequently face to get a large sample of participants. Individuals with ASD, especially children and adolescents, often have a very full agenda. Generally, they go to school, usually also practice after school activities and/or attend a therapy centre for receiving educational and psychological intervention programs. In such a context, participating in a study is yet another activity in an already busy week, even more so if that study is about a long-term intervention program that cannot really be incorporated as part of one of their regular activities. Limited resources that a given study could have in terms of budget and personnel may constitute a third factor contributing to the commonness of small samples. Unfortunately, not all research studies are funded and not all the funded projects acquire enough funds to afford the involvement of a higher number of participants. In many studies, most of the budget might be assigned to the development or purchase of HW and/or SW. Finally, a research idea frequently originates from the special needs of a specific person with ASD. A given intervention might benefit the skill development of that specific person, and hence that person forms the single participant in a first study.

Whichever is the reason why some of the reviewed papers included an intervention program that was developed and implemented for a single participant, the ASD community should take into consideration the consequences of this practice. All in all, the intervention might (a) be beneficial for improving a given skill, or group of skills, in that one participant, and (b) serve as a source of inspiration to others on the use of technology with people with similar characteristics to the participant involved. However, even if the primary study appears to indicate that the use of technology was highly effective for that one participant, this positive outcome cannot be generalised to other people with ASD. This fact may prevent other researchers from replicating findings of the primary study and, as a result, the chances for this intervention to become an established EBP may be minimal.

Another important finding is that the large majority of the studies reviewed included fewer than 10 participants. Whether such a number of participants is sufficient depends on the research design that is selected to evaluate the effectiveness of the intervention. Since a second variable (i.e., research design) plays a role here, this is discussed later on in a specific section dedicated to the bivariate results.

Gender. Findings are in accordance with previous reviews which indicate that participants in TMI studies are predominantly male (DiGennaro Reed et al., 2011; Knight et al., 2013; Pennington, 2010; Ramdoss, Lang et al., 2011). Epidemiological studies have reported that significantly more males than females are diagnosed with ASD at a ratio of around 4:1 (Fombonne, 2009). However, this ratio differs from the one identified in the studies reviewed (i.e., close to 6:1). The fact that half of the studies that provided gender information only included males might suggest that participation of females in TMI studies is less common. Besides, given that guidelines on how to conduct good research advise researchers to provide enough information to enable the replicability of the studies and accurate comparison of findings (Denscombe, 2002), the lack of information on participant gender noted in a number of studies may be considered a rather vital omission.

Age. The finding that interventions with primary school age participants were numerous while interventions with adult participants were more limited is in line with the observation that most of the previous reviews focused on the use of technology with children (e.g., DiGennaro Reed et al., 2011; Shukla-Mehta et al., 2010; Stromer et al., 2006). To the researcher's knowledge, no previous reviews focused on the use of technology with adults. There may be several explanations for this finding. Firstly, delivering interventions to younger participants might be more beneficial in terms of outcomes (Corsello, 2005; Dawson et al., 2010). Although the number of early-year children that participated in the studies reviewed was smaller than one would expect along with this explanation, this may be due to the fact that schooling is compulsory for primary aged children while it is optional for early years. Children who attend school may be easier to access than children who do not. Secondly, younger individuals are often considered *digital natives* (Prensky, 2001) and may therefore be a more relevant group to work with in studies involving ITs than adults.

Diagnosis. The diversity of diagnostic labels that have been identified in this review illustrates the lack of uniformity with regard to the diagnostic description of the participants. More precisely, it has been found that primary authors of the papers included in this review:

- Used a wide range of different ASD assessment tools (e.g., ADOS-2, ADI-R, CARS-2, GARS-2) that are based on different metrics and scoring systems.
- Used different diagnostic criteria. As described in Chapter 1: according to the DSM-IV-TR a person can be diagnosed with (a) autistic disorder, (b)

Asperger's disorder or (c) PDD-NOS; according to the DSM-5 a person can be diagnosed with ASD; and according to the ICD-10 a person can be diagnosed with (a) childhood autism, (b) atypical autism, (c) AS or (d) PDD, unspecified.

- Used PDD as a specific diagnosis when this is actually an umbrella term under which the specific diagnoses are defined. Moreover, according to DSM-IV-TR and ICD-10, PDD encompasses all the diagnoses of autism and some other related disorders that are no longer considered under the ASD diagnosis of the DSM-5 (e.g., Rett's Disorder).
- Used the diagnostic label of ASD in papers that were published long before the term was formally established as a diagnosis in 2013 with the publication of the DSM-5. Therefore, ASD might have been indistinctly used as synonym of PDD or as the current ASD diagnosis.
- Used the word *condition* instead of *disorder*, using the label ASC instead of ASD. Similar to the previous case, ASC might have been used as an alternative to PDD or as synonym of the ASD diagnosis.
- And used additional labels such as LFA/HFA or mild/moderate/severe autism.

Furthermore, some authors did not mention the use of any standardised assessment tool. Again others described the participants as, for instance, 'people with ASD without learning disability', without indicating the tool they used to make that assumption. It was also observed that the same participant that was involved in more than one study received a different diagnostic label in each study (e.g., ASD and autism). Apart from the diagnostic label, the participants' cognitive and language abilities, which are statements required by DSM-5 to specify an ASD diagnosis, were rarely described.

Together, the aforementioned issues make it very difficult to draw conclusions based on the participants' diagnoses. For instance, since only 12% of the papers clearly focused on participants with higher cognitive and language abilities and these participants had a diagnosis of mild autism, HFA or AS, one could have erroneously concluded that most papers included participants with lower abilities, when it is very likely that many other participants with also higher cognitive and language abilities and lower levels of ASD severity had been grouped under labels such as PDD, ASD or ASC. Thus, there is a clear need for detailed reporting with higher precision and without ambiguities not only on the diagnostic label but on other important characteristics of the individuals who participate in TMIs as well.

4.1.2 Technology

HW. It is not surprising that the PC has been the most widely used HW (see Table 1) given that this is the oldest HW identified in the reviewed papers and the overall ownership of PCs has not decreased with time (Anderson, 2015). Moreover, in more economically developed countries, the majority of population have access to one or several PCs in real-world settings such as home or school (Parsad, Jones, & Greene, 2005).

Tablets and smartphone/small handheld devices have also been highly chosen (see Table 1). This finding is in line with previous reviews that summarized the potential use of these portable devices in ASD interventions (Alzrayer et al., 2014; Kagohara et al., 2013; Lorah, Parnell et al., 2015; Mechling, 2011; Stephenson & Limbrick, 2015). The use of robots, despite their reputed high cost, appears to be prominent in the TMIs which were reviewed in this study. This has also been supported by previous studies reviewing the use of robots as effective tools in ASD therapy (Diehl et al., 2012; Scassellati et al., 2012).

Interestingly, no study implemented interventions with smart objects (i.e., tangible computing objects), even though these appear to be popular devices to be used with individuals with ASD (e.g., Escobedo, Ibarra, Hernández, Alvelais, & Tentori, 2014). Additionally, no study used smart watches, although recent literature has indicated that this technology could be useful for people with ASD (Torrado, Montoro, & Gómez, 2016).

SW. The fact that generic SW has been widely used in the reviewed studies (see Table 2) could be an indicator that researchers are looking at ways in which such SW can be used by individuals with special needs.

Another important finding is that a high number of studies have used special needs SW that is or was commercially available. This may indicate that SW for the special needs of people with ASD is well developed.

Several online catalogues offer a wide variety of apps for individuals with ASD (e.g., Autism Speaks: http://www.autismspeaks.org/autism-apps; Orange Foundation in Spain: http://www.appyautism.com/en/apps-searcher/; Development Autism Research Technology, DART, from the University of Edinburgh in Scotland: http://www.dart.ed.ac.uk/asdtech/app-reviews/). App searches can be filtered according to different criteria such as the type of device (e.g., tablet, smartphone), the required OS (e.g., Google Android, Apple iOS), or the price of the app. Moreover, what it is more valuable is that they indicate if a given app has received enough empirical support from research studies to consider it an EBP. Autism Speaks rates each app as (a) anecdotal, (b) research or (c) evidence. Orange Foundation indicates if there is scientific evidence by sharing a link to the research study that supports the effectiveness of the app. DART indicates a brief description (not based on a specific rating system) of each app's evidence base. This information is intended to be used by and fairly accessible to researchers, practitioners, parents and carers for selecting apps.

When choosing between two apps of similar characteristics, one might prefer the app that has empirical support. However, it appears that these resources do not always indicate each app's evidence accurately. For instance, the app *Proloquo2Go* was used in 10 of the 178 reviewed papers (Achmadi et al., 2012; Hill & Flores, 2014; Kagohara et al., 2010; Kagohara et al., 2012; Lorah, Karnes,

& Speight, 2015; McEwen, 2014; Roche et al., 2014; Van der Meer et al., 2011; Van der Meer et al., 2013; Van der Meer et al., 2014). Most of these research studies indicated effectiveness of Proloquo2Go. This app, that is a communicator to be used with iOS devices (i.e., Apple Watch, iTouch, iPhone, iPad) and has a current cost of $249.99 in the Apple Store, has been rated as anecdotal by Autism Speaks. Orange Foundation does not provide any link to relevant research, indicating that there is no scientific evidence to support this app. DART describes the evidence base of this app as inexistent. Based on these indications, a professional looking for an evidence-based app might reject the use of this one, especially due to its cost. However, if this professional sees that the app has a good rating score and there are links to several studies that indicate its effectiveness, the final decision might be different. Considering this, the users of these online resources need to be cautious when they use the EBP information that is given as a criterion for an app selection.

Another finding that is worth to bring into discussion is the fact that the same SW has been used in a high number of different studies. These studies were frequently led by the same authors, often research colleagues of authors of previous studies and sometimes independent researchers. One example is the aforementioned Proloquo2Go app. Another example is the *Mind Reading: The Interactive Guide to Emotions* program, which was used in six studies (Golan & Baron-Cohen, 2006; LaCava, Golan, Baron-Cohen, & Myles, 2007; LaCava, Rankin, Mahlios, Cook, & Simpson, 2010; Thomeer et al., 2011; Thomeer et al., 2015; Weinger & Depue, 2011). This could indicate an effort in the field for conducting studies using SW that appeared effective in previous studies, working out pilot studies to full studies, and addressing limitations and future directions provided in previous work. Moreover, several researchers might not be related to the development and commercialization of that specific SW and might not have any special interest in promoting its use. Finally, earlier work revealed the possibility of SW initially created for research becoming special needs SW in later studies (e.g., Beaumont & Sofronoff, 2008; Beaumont, Rotolone, & Sofronoff, 2015).

MoD. It is not surprising that interactive sequence and prompting have been the preferred methods for delivering the reviewed TMI studies (see Table 3) because techniques such as digital stories or video modelling have been highly used with individuals with ASD (Buggey & Hoomes, 2011; Gardner & Wolfe, 2013; Kokina & Kern, 2010).

An important gap detected regarding this feature has been the fact that only few studies compared the use of technology to the use of any other traditional method or to another piece of technology for teaching the same target skill. Therefore, the possibility of obtaining similar results by using traditional methods or simpler technology, which might mean fewer expenses to purchase pricey or more complex technology, was not considered by most of the reviewed studies.

4.1.3 Target skills

The finding that the vast majority of the reviewed studies targeted skills from a particular category (i.e., social communication and social interaction, academic or life skills) (see Figure 5) is in line with previous studies that reviewed papers whose aim was to improve skills that belonged to one specific category (DiGennaro Reed et al., 2011; Knight et al., 2013; Pennington, 2010; Ploog et al., 2013; Ramdoss et al., 2012; Ramdoss, Lang et al., 2011; Ramdoss, Mulloy et al., 2011; Shukla-Mehta et al., 2010; Wainer & Ingersoll, 2011). However, it needs to be noted that there is a great variance in the way previous studies have defined different skills, and this should be taken into consideration when drawing conclusions about the skills which have been targeted the most. For example, for Ramdoss, Lang et al. (2011) identification of vocabulary words and phonological awareness fall under the communication skills category, whereas vocabulary and letter identification belong to academic skills for Pennington (2010) and Knight et al. (2013). This finding shows the need to use widely accepted definitions and classifications for drawing more accurate comparisons and conclusions.

The fact that an important percentage of studies focused on social communication and social interaction skills (see Figure 5) is not surprising given that difficulties in these spheres have always been a defining characteristic of individuals with ASD (APA, 2013). The high number of studies focusing on academic skills is not surprising either, given that carers and teachers push for high academic attainments of students with disabilities, including ASD (Freeman & Alkin, 2000; Ivey, 2004). The fact that many studies focused on life skills echoes recent research stating that technology has been widely used to support daily life skills in individuals with ASD (Fletcher-Watson, 2014).

4.1.4 Research design

Considering the important contributions of SSD in special education (Horner et al., 2005; Mesibov & Shea, 2011), it is a positive finding that most of the reviewed studies have used this type of designs, especially multiple baseline and multiple probe designs (see Table 7), which are considered two of the most rigorous SSDs (Gast & Ledford, 2014).

The finding that is more disadvantageous is the high number of studies that have applied group designs without comparison or control group, given the entailed limitations of this practice (Gersten et al., 2005). Besides, the fact that there are group design studies with control group that did not allocate participants randomly to the groups is a limitation identified in this review.

Other considerations of this feature involve the number of participants so these are addressed later on in the section dedicated to the bivariate results.

4.1.5 Setting

The vast majority of the reviewed studies were –at least partially– conducted in real-world settings, addressing the need for more real-world research as it has been extensively highlighted by the current literature (Kasari & Smith, 2013; Parsons & Kasari, 2013). This finding echoes the DiGennaro Reed et al. (2011) review which revealed that many of the studies on teaching social skills to children with ASD via the use of technology were conducted in school settings (i.e., 18 of the 29 studies, 62%).

Results have shown that many studies were conducted in different settings, indicating that some participants received the intervention in a setting and other participants received the intervention in another setting, within the same study. Thus, the same participant did not practise the target skills across different settings. Taking into consideration that few studies of school-based interventions cater for generalisation and maintenance of the skills taught to children with ASD (Kossyvaki & Papoudi, 2016; Machalicek et al., 2008), and many individuals with ASD have difficulties in transferring skills from one setting to another (National Research Council, 2001), more studies across settings are needed.

4.1.6 Country

The findings related to country (see Table 8) are in accordance with literature in other ASD research (e.g., epidemiological studies), which has mainly been conducted in English-speaking high-income countries (Caronna, Milunsky, & Tager-Flusberg, 2008; Elsabbagh et al., 2012; Zaroff & Uhm, 2012). Many reasons can account for limited ASD research in other countries, the lack of available research funds being possibly the most prominent one. Additional factors that can contribute to this gap might be limited ASD awareness, different spiritual or religious views on disability (Grinker, 2009; Rogers-Adkinson, Ochoa, & Delgado, 2003; Mirza, Tareen, Davidson, & Rahman, 2009) and the psychoanalytical framework several countries still have in operation as the predominant way of working with individuals with ASD. Cultural attitudes towards ASD in particular, and towards disability in general, can greatly influence the importance placed on education and the funds spent on educational research (Ravindran & Myers, 2012). Limited technology access is another factor that might explain, at least partially, the lack of TMI studies in some countries that host other types of ASD research (e.g., India, Pakistan) (International Telecommunication Union, 2015). Therefore, the applicability of intervention studies developed in some countries to other countries may be limited and highly challenging.

The results from this feature should be interpreted considering that this review only included studies published in English. It is possible that studies conducted in other non-English speaking countries have been published in languages other than English, not being identified in this review.

4.1.7 Year

In terms of year of publication (see Figure 6), the findings are in line with recent reviews whose authors have pointed out the continuous increase in the number of publications in the field of TMIs and people with ASD (Fletcher-Watson, 2014; Grynszpan et al., 2014; Kientz et al., 2014). In accordance with this, it is clear that there is a growing interest in performing TMIs for individuals with ASD that might be facilitated by easier access to (a) technology and (b) previous intervention experiences that have been disseminated. A high number of TMIs for individuals with ASD have been presented at different international conferences recently (Autism-Europe International Congress, 2016; International Meeting for Autism Research, IMFAR, 2016; International Conference on ITs for people with ASD, ITASD, 2014). Another reason that may account for the significant increase in research on TMIs and ASD is the fact that it is a highly-prioritised area of research on the agenda of a number of charities and research councils (e.g., Medical Research Council, Economic and Social Research Council, Autistica, Engineering and Physical Sciences Research Council) (Pellicano, Dinsmore, & Charman, 2013).

4.1.8 Journal

Most of the TMI papers reviewed have been published in peer-reviewed journals widely used by researchers in the field of ASD (see Table 9). This finding is not in accordance with what previous reviews have highlighted (Fletcher-Watson, 2014), most probably due to the use of different databases for the search of papers.

There is a current interest of specialized journals in publishing on this topic. *Autism: The International Journal of Research and Practice* dedicated an entire special issue to TMIs for individuals with ASD (Bölte, Golan, Goodwin, & Zwaigenbaum, 2010). Similarly, a special issue of the *Journal of Behavioral Education* was dedicated to evaluating the use of technology in the education of individuals with severe learning difficulties, including ASD (Sigafoos, 2011). More recently, a special issue of the *Journal of Autism and Developmental Disorders* explored how advances in technology are changing and will continue to transform research and practice in individuals with ASD (Shic & Goodwin, 2015). Finally, *Research in Autism Spectrum Disorders* is currently preparing a special issue that is expected to be published in 2018 under Yuill, Parsons, Brosnan and Good's edition on digital technologies for people with ASD to support interaction and embodiment in the real world.

It is worth mentioning that the lack of information found in the reviewed features (e.g., gender of participants, setting where the study was conducted) does not seem to be related to the aim of the journals nor to their impact factors; papers lacking information were published in all types of journals.

4.2 Bivariate results

4.2.1 Number of participants and research design

It seems reasonable that most of the studies that included 10 participants or more applied group designs, while most of the studies that included fewer than 10 participants applied SSDs (see Figure 7). The fact that 146 studies included fewer than 10 participants, although it might not be ideal, it was somehow expected, given the previously described difficulties for getting a higher number of participants. What is actually surprising is that 13 of these studies applied group designs. Bearing in mind that data from 10 participants would be the minimum required for doing statistical analysis to evaluate the effectiveness of programs in group design studies (Reichow, 2011), the rigour of these 13 studies might be dubious. Although the reasons to apply group designs instead of SSDs were not explained, this could be indicating a general preference for these designs. Some researchers might be inclined towards the use of group designs due to their belief that SSDs do not have the strength of evidence of the former (Jovell & Navarro-Rubio, 1995). However, Mesibov and Shea (2011), among others (e.g., Odom et al., 2003; Smith et al., 2007), argue that ASD research should recognise the contributions from SSDs and qualitative research, because this research is significantly more practical and less expensive than the large RCTs that would be needed to demonstrate intervention effects given the heterogeneity of people with ASD.

It may not be disputable (or maybe yes, see for example Grossman & Mackenzie, 2005) that the RCT is the *gold standard* in clinical research (Sacket, 1994) and that this might be, therefore, the best research design to use in many cases. However, when it is not possible to carry out a RCT because of a small number of participants, it might be a safer option to evaluate the intervention effects through a multiple baseline SSD than using a group design without control group, for instance; the chances for controlling the threats to the internal validity of the study could be substantially diminished in the latter case. Considering this, it appears that the research design and how all the factors that could threaten the strength of the study are controlled is much more important than the actual sample size.

4.2.2 Age and target skills

Considering that most of the skills that are included in the social communication and social interaction category must be present at the early childhood of typically developing children (Rogers & Dawson, 2010), it is reasonable that many of the early years and primary age participants who lack at least one of these skills were involved in intervention studies that targeted this category. This finding is in line with previous reviews that have focused on the enhancement of social skills in children with ASD through the use of technology (DiGennaro Reed, 2011; Ploog et al., 2013; Ramdoss, Lang et al., 2011).

When children with ASD become adolescents, it is their performance at school and their academic achievements that are given priority (Fleury et al., 2014). Thus, it is not surprising that many secondary age participants took part in studies focusing on academic skills. This result is in line with a previous study that reviewed TMIs for adolescents with ASD finding that a number of studies focused on academic activities (Odom et al., 2015).

When adolescents start the transition into adulthood, the search for independence and job opportunities becomes a priority (Taylor & Seltzer, 2011). Therefore, it was expected that most post-secondary participants would be involved in intervention studies focusing on life skills. This finding is consistent with a previous study that reviewed life skills enhancement through technology in adults with ASD (Ayres, Mechling, & Sansosti, 2013).

4.2.3 Age and setting

Given that the access to primary and secondary age participants might be easier through schools, it appears reasonable that a high number of studies with primary and secondary age participants were conducted in schools.

Since adults with ASD are likely to be looking for a job, it was predictable that the studies that were conducted in vocational centres or work environments focused on post-secondary age participants. Besides, adults with ASD might be more prone to attend day centres or vocational centres than therapy centres, which appear to be more often dedicated to children and adolescents. Hence, it was expected that no studies that were conducted in the latter setting would include post-secondary age participants.

4.2.4 Technology HW and age

It is not surprising that PCs have been so widely used by primary and secondary age participants due to the putative higher access to this subcategory of HW in school settings of countries like US (Parsad et al., 2005).

The fact that smartphone/small handheld are portable devices provide better opportunities to learn skills that require one to move around, such as transitioning, which appear to be more targeted in older participants (Mechling & Savidge, 2011; Palmen, Didden, & Verhoeven, 2012). Given that these devices are made for being transported and are generally held in participants' hands, they might be more breakable than other subcategories of HW. This particularity might also account for the fact that they are highly used with older participants.

What was less expected is that tablets –HW that shares the abovementioned features with smartphone/small handheld devices– were not primarily used by older participants. The fact that there is a wide range of protection systems (e.g., cases, covers, screen protectors) and specially designed tablet desk and wall mount systems that are commercially available, can account for this result. All these accessories might make the use of these devices more accessible to participants of different ages and cognitive abilities requiring different levels of support (e.g., for doing daily living activities such as preparing food).

Since research literature indicates that robots could benefit individuals with ASD of all ages (Scassellati et al., 2012), it is an interesting finding that no studies used robots with post-secondary age participants. Many of the robots that have been used in the reviewed studies had a child appearance so they might not have been appropriate for adults. However, there are other widely used commercialised robots such as Nao, from Aldebaran Robotics, that have a look that is more universal; Nao has been found to be effective in several interventions with children with ASD (e.g., Barakova, Bajracharya, Willemsen, Lourens, & Huskens, 2015; Warren et al., 2015). It is worth mentioning that when this robot was presented in previous ASD conferences (e.g., IMFAR, 2016; ITASD, 2014), it attracted the attention and interest of some adults with ASD.

4.2.5 Technology HW, SW and MoD

It is worth highlighting the lack of studies that have used robots with SW that was not specifically developed for research. This finding might indicate that not much SW for robots is available, meaning that researchers need to develop their own SW. This finding is in line with previous reviews on the use of robots in ASD therapy (Scassellati et al., 2012).

One of the reasons that might explain why PCs were mostly used for delivering interactive sequence is that interactive sequences very often present visual stimuli and PCs generally have a bigger screen compared to other subcategories of HW.

The fact that smartphone/small handheld devices were mainly used for prompting might be explained by the advantage that prompts can be delivered to the person with ASD who is carrying one of these devices. Because these portable HW are more and more accessible, affordable and customizable, it would not be surprising if in the next years they are the most used for prompting.

Since most SW for virtual environments need the features of a PC to be executed (Parsons & Cobb, 2011), it was expected that this would be the most used HW for simulation. Likewise, since robots appear to be a potential HW for facilitating interaction among people with ASD (Scassellati et al., 2012), it is not surprising that most of the studies that delivered interactive agents used robots.

4.2.6 Technology HW, MoD and target skills

The finding that smartphone/small handheld devices were extensively used to teach life skills underlines that the fact that these devices can be easily transported makes them suitable for practicing skills such as transitioning or cooking (Mechling, Gast, & Seid, 2009; Mechling & Savidge, 2011). Since smartphone/small handheld devices were mostly used for prompting and for enhancing life skills, it was foreseen that prompting would also be the preferred MoD for teaching life skills.

It would be interesting to explore the potential use of generic tools like Siri (i.e., Apple's voice-controlled personal assistant), which is available for different HW including smartphone/small handheld devices and –due to its ability for delivering prompts and its presumed predictability, understanding and adaptability– could be useful for enhancing life skills among people with ASD. Although to the researcher's knowledge there are no studies on the use of Siri in ASD, promising personal experiences have been shared online (e.g., Newman, 2014).

The success of a TMI may depend on the skills of the person for using technology. Hence, learning how to better use technology could be considered one life skill that individuals with ASD may need to practise, especially before they use the technology for other purposes. Although one would expect to find studies enhancing the use of technology in this review, no studies fully focused on these skills; only a few papers considered them while their final aim was the enhancement of social communication and social interaction skills (Achmadi et al., 2012; Kagohara et al., 2010; Van der Meer et al., 2011).

4.2.7 Technology HW, MoD and setting

Given the practicality of using smartphone/small handheld devices for enhancing life skills, including work performance, it is not surprising that this HW has been widely used in vocational centres and work settings. Further, considering that prompting has been the most popular MoD for practicing life skills, it is not surprising that this was also the most used MoD in work settings.

In developed countries, it is more and more common to use tablets in different work environments for different purposes (e.g., to show the menu in restaurants or the new collection in a clothing store). However, no study fully focused on the use of tablets in work settings.

Since school might be the environment that offers more opportunities for interaction with peers, it is not surprising that this setting hosted all the studies that delivered collaborative games.

4.2.8 Technology HW, MoD and year

Since PC is the only HW that has been used along the whole period of the review and its use has not decreased with the years, it comes as no surprise why the PC has been significantly more used than any other HW. However, the number of studies using tablets, which did not exist before 2012, has increased in the last years probably due to the newness, the extended use and the commercial success of these devices. According to a recent research report, the ownership of tablets grew in the last years while the ownership of PCs stayed flat (Anderson, 2015). Considering this, it would not be surprising if in the next years the use of tablets overtakes the use of PCs. Another development that might contribute to an upcoming rise of tablet-mediated intervention studies is the ongoing increase in possibilities of tablets that used to be enabled by PCs only (e.g., storing large amounts of data) while still preserving the advantages of tablets (e.g., smaller, lighter, portable).

Another point that is worth bringing into discussion is that SGD has not been used after 2007 in any of the reviewed studies. This is most probably caused by the fact that the functions of the old SGD have been replaced by apps for tablets and smartphone/small handheld devices. What pictogram templates placed behind a plastic grid or mesh used to serve for in SGD is now available through selectable touch buttons in apps for tablets and smartphone/small handheld devices. There are over two hundred available apps for sentence composition and speech generation in the app markets. A recent review indicates that 93% of the participants with ASD that were included in 16 studies that used these apps in tablets and smartphone/small handheld devices acquired communication skills (Lorah, Parnell et al., 2015).

The abovementioned points taken together and the fact that tablets and smartphone/small handheld devices are becoming increasingly accessible, reduce the likelihood of seeing future research studies using traditional SGD.

4.2.9 Target skills and setting

Given that academic skills are part of the curriculum for school pupils, it was expected that schools would host most of the studies targeting academic skills. As expected, life skills were more targeted in studies that were conducted in day centres, vocational centres and work settings; these are settings where skills for the independence and labour market inclusion of the individuals with ASD might be practised more often. What is surprising is that no study targeting life skills (e.g., cooking, doing laundry) was conducted in homes.

4.2.10 Target skills and year

It is remarkable that until 2006 no TMI study focused on life skills. Several reasons might account for this finding such as (a) the development of portable devices –which were highly used later on in studies focusing on life skills– and (b) the fact that around that period influential ASD organisations called for a larger support and understanding of the independence of people with ASD (e.g., The National Autistic Society; Dowell, 2007).

4.2.11 Research design and year

Results indicated that most RCTs were conducted in recent years. When rigorously conducted, RCTs provide excellent opportunities for establishing causal conclusions between the intervention and the outcomes and can facilitate EBP development. Therefore, the finding that more and more TMI studies are applying RCTs is promising and will hopefully be continued.

4.3 Recommendations for future research

In the light of the results of this review, research in the field might consider the description of all the features analysed in this review due to their demonstrated importance.

With the steady increase in the numbers of girls and women receiving an ASD diagnosis (Fombonne, 2009), researchers need to make sure that females are adequately represented in their studies. Also, by including more females in future studies, it might be of novel interest to explore potential gender differences in the effectiveness of TMIs. This is very likely to occur as ASD manifest in different ways in males and females (Attwood, 2007). Since TMIs could also be beneficial to older individuals, more research needs to be conducted with adults with ASD of different cognitive and language abilities as well as levels of independent functioning. Participants' age and gender should be fully provided in future publications.

Furthermore, it would be desirable to report on the diagnosis of the participant in more detail by (a) specifying the diagnostic manual that was used to choose the diagnostic label (e.g., DSM-IV-TR; DSM-5; ICD-10) and (b) mentioning the diagnostic tools that were used to evaluate ASD and indicate the ASD severity (e.g., ADOS-2, ADI-R, CARS-2, GARS-3). Similarly, providing information on dual diagnosis, if there is any (e.g., ASD and ID; ASD and ADHD) is of significant importance. Besides, it is also crucial to report on key factors such as the level of cognitive abilities and receptive and expressive language, indicating the assessment tools that were used for each evaluation (e.g., WISC-IV, Leiter-3, BPVS-3). Providing all this information can enable researchers to draw conclusions and generalise the results more accurately as well as to replicate the study (Leppink & Pérez-Fuster, 2016).

Moreover, to evaluate the actual impact of the chosen technology, future research should compare the use of a given technology and that of traditional methods or other pieces of technology. Besides, exploring the effectiveness of robot-mediated interventions on older participants with ASD could inform future research. Furthermore, the research community may want to look at ways for developing SW for robots for the general public or for people with special needs that end up being commercialized. Doing so would facilitate its use to other interested users and would accelerate the replication of studies. Finally, future research may consider the need of training participants in the optimal use of technology to get the best out of the experience of teaching through technology.

The present review has offered an exhaustive list of the skills that have been targeted in the studies in this review (see Table 4), clearly indicating which skills have been included in each of the three categories. Future review studies may want to use this classification system, or a similar one, to provide a thorough list of skills and to bring closer and closer a consensus on skills classifications. Due to the importance of life skills for the wellbeing, independence and inclusion of individuals with ASD, future research should keep focusing on the enhancement of these skills. Moreover, studies focusing on life skills and studies focusing on social and academic skills should be considered equally important, because adults with ASD could operate more independently and children with ASD could be better prepared for the transition into adulthood.

Given the heterogeneity among individuals with ASD, it is desirable that methodologically strong SSDs are considered appropriate to evaluate the effectiveness of TMIs. Studies that choose group designs should include a comparison or control group and randomly allocate participants to the groups (i.e., RCT). Besides, the inclusion of a larger number of participants should be considered and the implementation of an intervention to an only participant should be avoided, unless it is exceptionally necessary. Regardless of the number of participants, the impact of the study might be mainly determined by the research design applied. For this reason, when it is possible, it would be recommended (a) to apply more sophisticated SSDs such as multiple baseline or multiple probe designs when the number of participants is small and (b) to apply a group design with control or comparison group –preferably with randomization– when the number of participants is larger.

Based on the literature and the present results, it seems that the ideal place for the conduction of a TMI study would be a setting where the person with ASD naturally performs the skills that are being enhanced through the use of technology. If, for instance, a teacher wants to enhance the social interaction skills of a primary school student through the use of technology, it would be recommended that researchers lead efforts for implementing the intervention in the school that the student attends, and evaluate the effectiveness of the intervention while the student is interacting in real situations with their classmates and/or school staff. Studies across settings should evaluate the generalisability of the acquired skills to other settings. Given the need for more work inclusion of individuals with ASD (Barnard, Prior, & Potter, 2000) and the increasing presence of tablets in work environments, more research studies focusing on the use of tablets in work settings would be of interest. Besides, it would be recommendable to do more research focusing on life skills in homes, where individuals with ASD can benefit from the practicality of the intervention. More country-specific research considering cultural differences and ASD perceptions might be needed in order to develop TMI approaches and test their applicability in local settings. Providing a description of the setting and the country where the study was conducted is of significant importance.

Moreover, it would be of particular benefit if research studies, which include individuals with ASD, are published in journals that specialise in ASD, or at least in special educational needs, so that experts in the field are more likely to have checked the research gaps these studies attempt to fill, their accuracy and rigour, and their ethical procedures.

4.4 Limitations

One of the limitations of this review might be the 15-year period during which the studies were collected. However, the reason for this is that the researcher sought to offer an overview of studies that implemented interventions with technology that can be found in the present day and used by other researchers who wish to replicate or follow future directions suggested in the primary studies. Some other limitations of this review can be that technology commercial brands (e.g., iPad, iPhone) or languages other than English were not included in the search. It was expected that primary studies would indicate the device, rather than the brand chosen, and English is generally requested by the international journals that are included in the selected databases. Another limitation might be that computer science databases (e.g., Association for Computing Machinery [ACM] Digital Library, IEEExplore Digital Library) were not considered. The researcher felt that TMI papers, beyond the development and usability studies that are often presented in most common computer science conferences (e.g., the ACM International Conference of Human-Computer Interaction [CHI]), are much more likely to be published in journals covered by the four databases used. A final limitation of this study is that IOA was not calculated for the selection and information extraction of the papers that were published in 2015 due to time and resource limitations. However, the excellent IOA statistics for 2000-2014 support the assumption that the researcher could manage to accurately extract information from papers published in 2015.

5 Conclusion

The purpose of this systematic review has been to offer an overview of TMI studies for individuals with ASD in order to describe current trends and to identify research gaps. To sum up, the majority of the TMI studies were applied to primary school male participants using PCs with generic and special needs SW to deliver interactive sequences, and for enhancing social communication and social interaction skills. Most of the studies included a small number of participants and SSDs were primarily applied. Studies were predominantly conducted in real-world settings, especially in schools, with a very high number taking place in the US. The tendency in publishing TMI papers for ASD is increasing and growth has been more significant in recent years, especially during 2015 which is the year that accounts for nearly a quarter of the studies included in this review. The papers were principally published in ASD-specialised journals. A number of methodological limitations of primary studies have been identified, the lack of information on participants' characteristics and the type of research design used being the most prominent ones. Including bigger samples with more females and adults, fully providing participant characteristics, and strengthening the studies by choosing a more appropriate research design, are some of the key recommendations given for future research. Overall, this review offers a systematic method for classifying TMI studies that can be used by other researchers to replicate the analyses and monitor whether trends remain or change in near future. It can also be argued that this work is the largest systematic review in the field; the list of the papers that have been reviewed can be highly valuable for conducting future reviews as well as empirical studies in the context of using technology for enhancing skills in individuals with ASD.

Chapter 3

Study 2. Enhancing JA skills in Individuals with ASD through TMIs: a Systematic Review and EBP Evaluation

1 Introduction

As explained in Chapter 1, JA has been identified as a profound difficulty among children with ASD (Mundy et al., 1986; Mundy et al., 1990). Literature to date suggests that behavioural and JA targeted intervention studies can be effective in increasing IJA (i.e., use of eye contact, gaze shifting and gestures to direct the attention of a social partner to a referent of interest) and RJA skills (i.e., to response by gaze following, pointing or showing to enhance social interaction with others), partially contributing to the improvement of other critical developmental areas, including social and language skills such as social initiations, positive affect, imitation and spontaneous speech in children with ASD (Ferraioli & Harris, 2011; Kasari et al., 2006; Kasari et al., 2008; Kasari et al., 2010; Martins & Harris, 2006; Rocha et al., 2007; Taylor & Hoch, 2008; Whalen & Schreibman, 2003; Zercher et al., 2001).

1.1 Relevant findings from Study 1

As revealed by Study 1, the use of technology for enhancing social communication and social interaction in individuals with ASD appears to be growing continuously. Previous reviews indicated that TMIs can be an effective strategy for the improvement of social communication and social interaction skills (e.g., Ramdoss, Lang et al., 2011; Wainer & Ingersoll, 2011). However, JA skills have been grouped under the umbrella terms *social communication* and *social interaction* skills in these previous studies. Thus, the effects of previous TMI studies on the enhancement of JA skills in individuals with ASD still remains unknown.

Apart from IT developments and an increased interest in the use of ITs for enhancing skills among individuals with ASD, Study 1 identified a number of flaws of studies carried out since the early 2000s. Several methodological weaknesses were reported (e.g., small samples and lack of detailed descriptions of participant age, gender and diagnosis). Previous reviews on the use of technology for people with ASD also highlighted the lack of research rigour of many primary studies when assessing the effectiveness of interventions (Knight et al., 2013; Pennington, 2010; Ploog et al., 2013; Ramdoss, Lang et al., 2011; Wainer & Ingersoll, 2011). These findings together may indicate a lack of EBPs in the field.

1.2 Evaluation of EBP

1.2.1 Quality indicators

Some researchers have developed guidelines, which include a number of quality indicators, for determining if a given intervention can be considered an EBP. These guidelines can be widely used, from evaluating proposals and assisting in the development of research plans to the establishment of EBP once the study has been implemented. Guidelines have been developed for SSDs and group designs, respectively. Horner et al. (2005) developed a method with objective criteria (i.e., 21 quality indicators) for determining when SSDs results are sufficient for documenting EBP within special education. Some years later, the What Works Clearinghouse (WWC) of the U.S. Department of Education released technical documentation (Kratochwill et al., 2010) with criteria to determine whether a SSD (a) *meets evidence standards*, (b) *meets evidence standards with reservations* or (c) *does not meet evidence standards*. This report also includes criteria for determining if the studies that meet evidence standards –with and without reservations– provide (a) *strong evidence*, (b) *moderate evidence* or (c) *no evidence* of a relation between an independent variable and a dependent variable. Another group of researchers (Logan, Hickman, Harris, & Heriza, 2008) developed guidelines for determining five levels of evidence and, based on Horner et al.'s (2005) criteria, they listed 14 rigour questions for establishing quality ratings (i.e., *strong*, *moderate*, *weak*) for SDDs in the field of medicine. Besides, Gersten et al., (2005) developed essential and desirable quality indicators (i.e., 21 for research proposals and 18 for research studies) and suggested a standard for determining EBP for group designs in special education. To this end, the APA's Division 12 Task Force developed criteria for both SSDs and group designs according to which a psychotherapy can be (a) *well-established* or (b) *probably efficacious* (Chambless & Hollon, 1998). More recently, Reichow, Volkmar, & Cicchetti (2008) have developed a method for evaluating and determining EBP for individuals with ASD. Their method includes: (a) primary and secondary quality indicators (i.e., 12 for SSDs and 14 for group designs); (b) guidelines for determining the research report strength (i.e., *strong*, *adequate* or *weak*); and (c) criteria for establishing different levels of EBP (i.e., *established* or *promising*).

1.2.2 Research synthesis organisations

The abovementioned guidelines are frequently applied and further developed by agencies and research synthesis organisations to systematically evaluate and aggregate findings from the research literature. There is a number of synthesis organisations. The largest and longest standing one is the aforementioned Cochrane Collaboration (http://www.cochrane.org), which focuses on medical and health research; the Campbell Collaboration (http://www.campbellcollaboration.org) focuses on education and the social sciences; and the WWC (http://ies.ed.gov/ncee/wwc/) focuses on educational practices. In the field of special educational needs, it is also worth mentioning the National Technical Assistance Center on Transition (NTACT) of the U.S. Department of Education, which uses quality indicators to label practices for students with disabilities as (a) *evidence-based*, (b) *research-based*, (c) *promising* or (d) *unestablished* (http://transitionta.org/effectivepractices). Further, more precisely for the promotion of EBP in the field of ASD, the National Autism Center (NAC) applies quality indicators for classifying ASD interventions as (a) *established*, (b) *emerging* or (c) *unestablished* (Green, Ricciardi, & Boyd, 2009).

Reviews provided by these resources are intended to help researchers find the best EBP, which can be therefore used for replication (Leppink & Pérez-Fuster, 2016) or to better design their own empirical and review studies. To the researcher’s knowledge, no study reviewing the effectiveness of TMIs in ASD has been considered by any of these organisations yet. This might be due to the lack of reviews indicating strong research rigor and high levels of evidence of TMI studies.

1.3 Scope of the study

The present study has a twofold objective: (a) to systematically review TMI studies which focused on the improvement of JA skills in individuals with ASD, and (b) to determine the research quality and the level of evidence achieved by these studies.

2 Method

2.1 Systematic review

2.1.1 Search procedure

Since the search procedure that was led in Study 1 was broad enough for identifying the papers that could match the purpose of this study, no further searches were conducted.

2.1.2 Inclusion and exclusion criteria

Likewise, the inclusion and exclusion criteria that applied in Study 1 were suitable for this study as well. Thus, the set of 178 papers included in Study 1 constituted the initial poll for identifying papers for Study 2. However, as the focus of this study was more precise, one additional inclusion criterion was considered for Study 2: each paper had to focus on the improvement of, at least, one JA skill (e.g., pointing, gaze following) as a dependent variable.

2.1.3 Study selection and extraction of information

After applying the additional inclusion criterion to the 178 papers, five papers were selected to be included in this study. The features of interest were the same as the ones considered in Study 1 with the addition of specific JA skills. Therefore, the information that was extracted from the five papers for Study 1 has also been presented here alongside the target JA skills in Table 10. Since the number of papers included in this study was manageable, this allowed for a more in-depth analysis. Thus, a new revision was conducted throughout the five papers to get more detailed information on the reviewed features such as, for instance, the specific type of robot that was used in the study.

2.2 EBP evaluation

Reichow et al.'s (2008) evaluative method was applied to the five papers that were included in the systematic review. This standardized method was selected amongst all of the other available ones because (a) it has been specifically developed to evaluate the empirical evidence of interventions for individuals with ASD and (b) it enables evaluation of a combination of different research methodologies: SSDs and group designs. Moreover, this evaluative method has been effectively used in previous studies that have reviewed other types of ASD interventions (Kossyvaki & Papoudi, 2016). Reichow et al.'s method was applied for (a) evaluating the research reports rigour, (b) evaluating the research reports strength and (c) determining if the interventions reviewed have the evidence needed to be considered EBP (see the evaluation tools in Appendix D).

3 Results

3.1 Systematic review

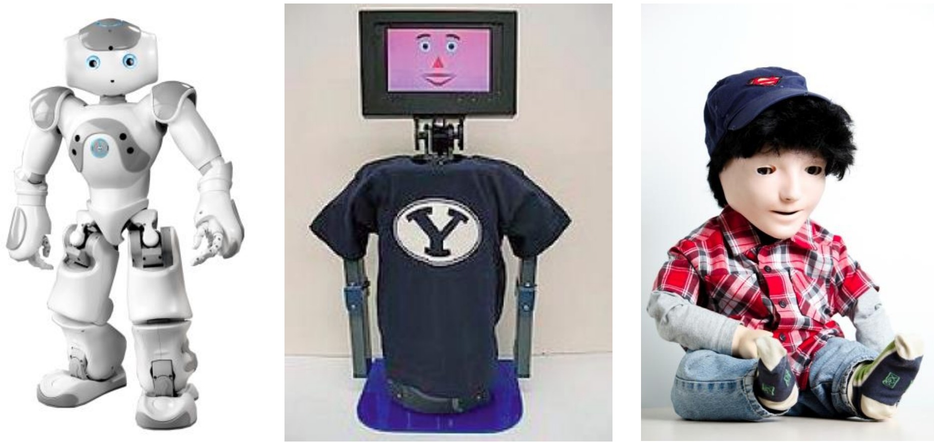
3.1.1 Participant characteristics

A total of 23 individuals participated in the five studies that were included. All of them were males between 2 and 12 years of age. With regard to the diagnosis, each study used different diagnostic labels and a variety, and in some cases absence, of diagnostic instruments. Warren et al. (2015) included participants with ASD who were diagnosed according to the DSM-IV-TR criteria (APA, 2000) and using the ADOS (Lord et al., 1999). Goodrich et al. (2012) also included participants with ASD. However, although behaviours and symptoms of the participants were described, they did not mention the use of any specific instrument. Tapus et al. (2012) involved participants with moderate and severe autism according to the CARS (Schopler, Reichler, DeVellis, & Daly, 1980). Neither Cheng and Huang (2012) nor Costa, Lehmann, Dautenhahn, Robins, and Soares (2015) indicated the instruments they used to diagnose their participants with PDD and autism, respectively.

3.1.2 Technology

Robot was the technology item used in four of the five studies. The type of robot and the additional elements used in combination with it varied across the studies. Two of them utilized the Nao robot. This is a 25 degrees of freedom humanoid robot, developed by Aldebaran Robotics, equipped with various sensors, two cameras and eyes with eight full-colour red-green-blue light-emitting diodes. Tapus et al. (2012) used Nao with a Kinect sensor to give the robot the ability to perform skeleton tracking. Warren et al. (2015) used Nao with a remote desktop Tobii120 eye tracker to monitor participants' eye gaze during task performance. Goodrich et al. (2012) developed the robot Troy, which is formed of a seven-inch computer screen for a face and movable arms. They used it in combination with a Wii controller to direct the robot according to activities and participants' actions. And Costa et al. (2015) used the robot KASPAR, a 17 degrees of freedom humanoid robot equipped with multiple touch sensors. They also used a keyboard to trigger the robot's responses. In the four studies, robots were used as an interactive agent: participants were positioned in front of the robot, either sitting or standing, to interact with it (see the robots in Figure 8).

The other type of technology used for improving JA in children with ASD was the Virtual Reality (VR), which was presented on a projection screen through one PC and two projectors (Cheng & Huang, 2012). Participants used a keyboard and also *data glove*, which is an input device for human-computer interaction worn like a glove that enables fine-motion control in robotics and VR. The SW, called Joint Attention Skills Learning (JASL), was specifically developed for the study and it offered a virtual environment that (a) simulated real-life situations for participants to navigate through and (b) displayed virtual characters for participants to interact with and learn from (see the JASL system in Figure 9).



Nao Troy KASPAR

Figure 8. Robots used in the reviewed studies.

Figure 9. One of the scenarios of the JASL system. Adopted from "Using virtual reality environment to improve joint attention associated with pervasive developmental disorder," by Y. Cheng and R. Huang, 2012, *Research in Developmental Disabilities, 33,* p. 2143. Copyright 2012 by Elsevier Ltd.

None of the five studies compared the effect of the selected technology item to other types of technology. Most of the studies did not compare the use of technology to the use of any other traditional method that does not use technology. Only Tapus et al. (2012) evaluated the effect of the interaction with the robot compared to the interaction with a human partner. All but one studies based the entire intervention sessions on the use of the abovementioned technologies. Only Goodrich et al. (2012) included the use of the robot as a part of a wider therapy framework that included a variety of classical behavioural techniques.

3.1.3 JA skills

All of the studies indicated the presence of JA difficulties in the participants before the intervention but only one used a standardized tool (i.e., the RJA item of the ADOS; Lord et al., 1999) to verify these (Warren et al., 2015). All but this study evaluated the JA outcomes with tools and activities that were developed for the specific research.

More precisely, the studies targeted a wide range of IJA and RJA. Cheng & Huang (2012) focused on the enhancement of the IJA skills of showing and sharing, and the RJA skills of pointing and showing. Costa et al. (2015) targeted the IJA skills of touching the robot and pointing, and the RJA skills of following the robot by looking at him, following his eyes gaze, touching him, pointing at him and moving the head. Goodrich et al. (2012) focused on the IJA skills of using eye gaze, pointing and gestures to direct the other's attention, and the RJA skills of following the robot with eye gaze, head turn and pointing. Tapus et al. (2012) focused on initiating gross motor actions while gazing the robot or the human with and without prompts, and on the RJA skill of following the partner's eye gaze. Finally, Warren et al. (2015) focused on the RJA skill of turning to look at the correct target.

Altogether, the most targeted IJA skills across the studies were looking and pointing spontaneously to direct the partner's gaze towards an object or event of interest. The most targeted RJA skills were following eye gaze, turning the head and pointing in response to a partner's action or request. All of the studies provided opportunities to both interactive partners (i.e., robot and participant, virtual character and participant, human and participant) to initiate and respond to verbal and non-verbal behaviours. However, the intervention studies of Cheng and Huang (2012), Goodrich et al. (2012) and Tapus et al. (2012) focused on the enhancement of both IJA and RJA whereas Costa et al.'s (2015) mainly focused on RJA and Warren et al.'s (2015) only focused on the enhancement of RJA. Thus, the reviewed papers targeted more RJA than IJA skills.

3.1.4 Research design

Three studies applied different SSDs: Goodrich et al. (2012) applied an AB design, Tapus et al. (2012) applied an ABAC design, and Cheng and Huang (2012) applied a multiple probe design. Warren et al. (2015) used an exploratory approach in which they analysed data for each participant individually and as a group. Since most of the data analysis included group data, this study has been classified as group design. Costa et al. (2015) also applied a group design.

3.1.5 Setting

Three of the five reviewed studies were implemented in laboratories located in universities or research centres (Cheng & Huang, 2012; Tapus et al., 2012; Warren et al., 2015). In these studies, the intervention was delivered in settings that were unfamiliar to the participants. Goodrich et al. (2012) did not provide information on the setting where the intervention was conducted, but it could be inferred from the paper that it took place in a clinic where participants had previously received other types of intervention. Costa et al. (2015) was the only study that was conducted in a primary school for children with special needs.

3.1.6 Country

US was the country of origin for two papers. One study was conducted in the UK, another study in Romania, and one in Taiwan. Thus, scientists across three continents (i.e., America, Europe and Asia) conducted studies on this research topic.

3.1.7 Year

Although the search included papers published from 2000, the first three papers that targeted JA skills in individuals with ASD through the use of technology were not published until 2012. The other two papers were published in 2015. This means that the five papers reviewed were published in the last five years.

3.1.8 Journal

The five reviewed papers were published in five different journals which are all included in the JCR (Thomson Reuters, 2016). These are: Research in Developmental Disabilities, IF= 1.877; International Journal of Social Robotics, IF= 1.407; IEEE Intelligent Systems, IF= 3.532; Interaction Studies, IF= 0.535; and Journal of Autism and Developmental Disorders, IF= 3.493. According to the journals' aim and focus, two of the studies were published in ASD and special needs journals (Cheng & Huang, 2012; Warren et al., 2015), another two were published in computer science and technology journals (Costa et al., 2015; Goodrich et al., 2012), and one paper was published in a journal that has an interdisciplinary focus on computer science and technology, psychology, education and medicine (Tapus et al., 2012).

Table 10. Information of the reviewed studies.

	Study	Journal	Participants' characteristics			Technology			JA skills	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
1	Cheng & Huang (2012)	Research in Developmental Disabilities	3 males	9-12	PDD	PC	Research	Interactive agent, simulation	Pointing, showing, sharing, interaction	SSD	Multiple probe	Laboratory	Taiwan
2	Costa et al. (2015)	International Journal of Social Robotics	8 males	6-9	Autism	Robot	Research	Interactive agent	Following, looking, eye gaze, pointing, head movement, touching	GD	Without control group	School	UK
3	Goodrich et al. (2012)	IEEE Intelligent Systems	2 males	3-8	ASD	Robot	Research	Interactive agent	Using/following: eye gaze, pointing, head turn	SSD	AB	N/A	US
4	Tapus et al. (2012)	Interaction Studies	4 males	2-6	Moderate autism, severe autism	Robot	Research	Interactive agent	Initiating motor actions while gazing, eye gaze, gaze shifting	SSD	Alternating treatment	Laboratory	Romania
5	Warren et al. (2015)	Journal of Autism and Developmental Disorders	6 males	2-4	ASD	Robot	Research	Interactive agent	Turning to look at a pointed target	GD	Without control group	Laboratory	US

3.2 EBP evaluation

Regarding the report rigour, all of the reviewed studies scored many *unacceptable quality* ratings for the primary indicators and also got many *there is no evidence* for the secondary indicators (see Table 11 and Table 12). All of the studies with the exception of one defined the dependent and independent variables in sufficient detail and indicated a reliable score for inter-observer agreement (IOA) or Kappa coefficient. However, in none of the studies the raters were blind to the treatment condition and no study assessed the procedural fidelity. Most studies did not get a high rating on the indicator for participant characteristics because they did not provide adequate information on the characteristics of the interventionists. One of the studies did not even give basic information such as gender; the researcher is aware that Warren et al. (2015) included six males due to a previously published conference paper based on the same research report (Zheng et al., 2013). None of the studies catered for generalisation and only one assessed the maintenance of the target skills. With regard to the social validity, all studies included dependent variables that are socially important but most had interventionists who were not familiar with the participants and vice versa.

None of the two studies that applied group designs (Costa et al., 2015; Warren et al., 2015) included a control or comparison group. Although both studies included data analyses that were well linked to the research questions, the sample sizes were too small. No study indicated the effect size of the interventions.

Only one of the three SSDs (Cheng & Huang, 2012) applied a design that was rigorous enough (i.e., multiple probe, see also Study 1) to obtain high ratings on the indicators for baseline condition, visual analysis and experimental control.

Due to the numerous unsuccessful rigour ratings obtained by each study, none of them received strong or even adequate strength ratings (see Table 13). Thus, although the reviewed interventions were effective for 21 of the 23 participants involved, these cannot be considered EBP.

Table 11. Scores for the studies using group designs.

Study	Rigour rating													
	Primary quality indicators						Secondary quality indicators							
	PART	IV	CC	DV	LRQ	STAT	RA	IOA	BR	FID	ATR	G/M	ES	SV
Costa et al. (2015)	A	H	U	H	H	U	N	Y	N	N	N	N	N	Y
Warren et al. (2015)	U	H	U	H	H	U	N	N	N	N	N	N	N	N

Note. PART: participant characteristics; IV: independent variable; CC: comparison condition; DV: dependent variable; LRQ: link between research question and data analysis; STAT: Use of statistical tests; RA: random assignment; IOA: inter-observer agreement; BR: blind raters; FID: fidelity; ATR: attrition; G/M: generalisation and/or maintenance; ES: effect size; SV: social validity; H: high quality; A: acceptable quality; U: unacceptable quality; Y: there is evidence; N: there is no evidence. Rating form adapted from "Development, Procedures, and Application of the Evaluative Method for Determining Evidence-Based Practices in Autism," by B. Reichow, 2011. In B. Reichow, P. Doehring, D. V. Cicchetti & F. R. Volkmar (Eds.), *Evidence-based practices and treatments for children with autism*, p. 38. Copyright 2011 by Springer Science+Business Media

Table 12. Scores for the studies using SSDs.

Study	Rigour rating											
	Primary quality indicators						Secondary quality indicators					
	PART	IV	DV	BSLN	VIS AN	EXP CON	IOA	KAP	FID	BR	G/M	SV
Cheng & Huang (2012)	U	H	H	H	H	H	Y	N	N	N	Y	Y
Goodrich et al. (2012)	H	U	U	U	U	U	Y	N	N	N	N	Y
Tapus et al. (2012)	U	H	H	A	U	U	N	Y	N	N	N	N

Note. PART: participant characteristics; IV: independent variable; DV: dependent variable; BSLN: baseline condition; VIS AN: visual analysis; EXP CON: experimental control; IOA: interobserver agreement; KAP: Kappa; FID: fidelity; BR: blind raters; G/M: generalisation and/or maintenance; SV: social validity; H: high quality; A: acceptable quality; U: unacceptable quality; Y: there is evidence; N: there is no evidence. Rating form adapted from "Development, Procedures, and Application of the Evaluative Method for Determining Evidence-Based Practices in Autism," by B. Reichow, 2011. In B. Reichow, P. Doehring, D. V. Cicchetti & F. R. Volkmar (Eds.), *Evidence-based practices and treatments for children with autism*, p. 38. Copyright 2011 by Springer Science+Business Media.

Table 13. EBP status of TMIs to enhance JA skills in individuals with ASD.

Study	Research method	Strength rating	Successful *N* / Total *N*
Cheng & Huang (2012)	SSD	W	3/3
Costa et al. (2015)	GD	W	8/8
Goodrich et al. (2012)	SSD	W	2/2
Tapus et al. (2012)	SSD	W	2/4
Warren et al. (2015)	GD	W	6/6
Number of group *studies* with strong rigour rating			$0 = Group_S$
Number of group *studies* with adequate rigour rating			$0 = Group_A$
Number of *participants* from single-subject studies with strong rigour rating			$0 = SSD_S$
Number of *participants* from single-subject studies with adequate rigour rating			$0 = SSD_A$

Formula for determining EBP status

$$(Group_S * 30) + (Group_A * 15) + (SSD_S * 4) + (SSD_A * 2) = Z$$
$$(0*30) + (0*15) + (0*4) + (0*2) = Z$$
$$0 = Z$$

Points (Z)	0 10 20 30	31 40 50 59	60+
EBP status	Not an EBP	Promising EBP	Established EBP

Note. S: strong; A: adequate; W: weak. Worksheet adapted from "Development, Procedures, and Application of the Evaluative Method for Determining Evidence-Based Practices in Autism," by B. Reichow, 2011. In B. Reichow, P. Doehring, D. V. Cicchetti & F. R. Volkmar (Eds.), *Evidence-based practices and treatments for children with autism,* p. 39. Copyright 2011 by Springer Science+Business Media.

4 Discussion

4.1 Systematic review

4.1.1 Participant characteristics

Regarding the number and gender of participants, results are in accordance with Study 1 and other previous reviews on TMIs which indicated that samples are often small and participants are predominantly male (DiGennaro Reed et al., 2011; Knight et al., 2013; Pennington, 2010; Ramdoss, Lang et al., 2011). However, the absolute absence of females in the present review does not match with epidemiological studies, which indicate that (a) males and females are diagnosed with ASD at a ratio of around 4:1 and (b) there is an increase in the number of females receiving an ASD diagnosis (Fombonne, 2009). Since JA difficulties equally affect males and females with ASD (Mundy, 2016), researchers need to make sure that both genders are appropriately represented in their studies.

The fact that the reviewed studies involved only children as participants is not surprising as JA skills are naturally developed during infancy and it is during this period when the plasticity of the brain better facilitates the development of such skills (Rogers & Dawson, 2010).

Concerning the diagnosis, results showed lack of uniformity that was also reported in Study 1; there was (a) a broad variety of diagnostic labels, including non-existing labels (i.e., PDD) and (b) a wide range of diagnostic criteria and assessment tools, including cases in which this information was not provided. This illustrated once more the impossibility of drawing conclusions based on participants' diagnoses. Future studies should provide a full description of the characteristics of the participants, including all the instruments that were used in the assessments. Providing this information would facilitate inference and it would encourage other researchers to replicate the studies.

4.1.2 Technology

Having in mind all the pieces of technology that are used in other TMIs for individuals with ASD (e.g., PC, tablet, smartphone/small handheld device), robots might better fulfil a variety of human-like functions and can potentially be used more successfully to improve social skills (Diehl et al., 2012). Since a social partner is needed for practicing JA skills, it is not surprising that most of the reviewed studies have chosen robots to mediate the intervention. More precisely, they have used child-sized humanoid robots, which might be considered good partners to practice with in order to generalise the learnt skills to the real world. The primary authors of the reviewed studies indicated that the use of robots was overall effective in improving JA skills. If these findings are reliable, they should be explained by the fact that individuals with ASD appear to be more intrinsically interested in the intervention when it involves electronic or robotic components (Robins, Dautenhahn, & Dubowski, 2006). However, it remains unknown if the improvements observed within the therapy context could be generalised to other contexts (e.g., interacting with peers).

It is worthwhile to mention the Goodrich et al.'s (2012) initiative of using the robot as part of a wider therapy that includes other non-technology-based teaching methods. This type of research study might be useful to evaluate the actual benefit of using technology in comparison with other traditional strategies. However, they did not manage to isolate the effects of the robot from the effects of the other methodologies on the improvement of the JA skills. Future research might consider this interesting approach by applying a research design that enables the evaluation of the contribution of robot use.

VR is the other technology that was used to enhance JA skills. Although VR might not offer a physical and tangible item as the robot does, it can show an interactive agent (i.e., virtual character). Moreover, this technology allows the participant to see him/herself reflected on the screen in form of avatar, his/her live image or his/her skeleton. It also allows the child to interact with and manipulate objects that are present in the virtual environment. All these features appear to be important contributors for the learning processes of individuals with ASD (Herrera, Jordan, & Gimeno, 2006). This might explain, at least partially, the JA improvements found by Cheng and Huang (2012).

Technology access and affordance are two important features to consider. Nao robot is a commercially available item. However, its last version roughly costs $9,000, an unaffordable price for many who might be interested in enhancing JA skills (e.g., researchers, clinicians, teachers, let alone parents). Moreover, the researchers who used Nao added other components to the system and developed themselves specific SW that is not widely available. This means that, although a person might get a commercial version of Nao, the chance of replicating the published studies are slim. Likewise, Troy and KASPAR robots, and their corresponding SW, are not available to the general public nor to the research community. Although the HW that is needed to show VR environments is fully accessible (e.g., PC, projection screen), the JASL program was specifically developed for the reviewed study and the access to it might be restricted. A great relevant ethical implication here is the fact that participants who have benefitted from the use of a given technology, should be entitled to have access to it once the study is over. This might be more feasible when the technology items are not high-cost or they are not prototypes in progress. For instance, the Robotics Institute of the Universitat de València created a set of video games for Kinect (*Pictogram Room*) that was specially developed to enhance a wide range of skills on individuals with ASD, including JA (Casas, Herrera, Coma, & Fernández, 2012). These are available in different languages and its full version can be downloaded for free with unlimitedly uses. Only the acquisition of easily accessible HW (i.e., PC, Kinect, projector and screen projection/white wall) is needed to use this system.

Furthermore, portable electronic devices such as tablets or smartphone/small handheld devices are more and more accessible and affordable. There is a range of apps for these devices available in the apps markets (e.g., Apple Store, Google Play) that can be downloaded for free or at a very low cost. One of these apps is *Joint Attention Training*, which offers different scenarios where the player can practice JA skills such as pointing by following the gaze of different characters. Although to the researcher's knowledge no study has used tablets or smartphone/small handheld devices for enhancing JA skills, they have been helpful for teaching individuals with ASD other social communication skills (Alzrayer et al., 2014; Kagohara et al., 2013).

Regardless of the piece of technology selected for the study, there are three aspects that future research might consider: (a) the assessment of the generalisation of the skills to real-world situations to know the practical benefit of the intervention, (b) the comparison of the effects of TMIs to the effects of human-mediated interventions to evaluate the contribution of technology, and (c) the comparison of the effects across different types of technology to better know which one contributes more to the enhancement of JA (e.g., robot vs. virtual character).

4.1.3 JA skills

A wide range of JA skills were targeted across the studies, especially the RJA skills of following eye gaze, turning the head and pointing in response to a partner's action or request. It does not come as a surprise the finding that RJA skills have been more targeted than IJA skills due to three main reasons. Firstly, some of the participants included were at the preverbal stage, which according to the literature, this is the period in which infants with ASD show more RJA difficulties compared to TD infants (Carpenter et al., 2002; Dawson et al., 1998; Paparella et al., 2011). Considering the levels of ASD severity described for some of the participants, one can infer –studies did not clearly provide this information– that some of them who were older could be minimally verbal, and therefore, eligible for benefitting from interventions focused on RJA skills. Secondly, many individuals with ASD rarely present spontaneous communication and find it especially difficult to initiate social interactions (Jordan, 2005; Kossyvaki, Jones, & Guldberg, 2012; Kossyvaki, Jones, & Guldberg, 2016). Thirdly, since it is also more likely to observe learning outcomes when the intervention focuses on the enhancement of RJA skills (Kasari et al., 2006; Whalen & Schreibman, 2003), researchers might be more prone to focus on this group of JA skills.

Knowing how JA abilities and difficulties are assessed before, during and after the intervention is important, not only for facilitating the replication of the study but also for evaluating with more precision the learning outcomes within, and even more outside the intervention context. Establishing levels of JA based on parents and teachers' records, or scores obtained through self-developed tools can be problematic. However, the available standardised tools might not cover the specific behaviours the researchers' want to evaluate. In these cases, using self-developed tools may be a reasonable option as long as the use of available standardised assessments such as the ESCS (Mundy et al., 2003) or the RJA item of the ADOS-2 (Lord et al., 2012) is considered alongside.

It is worth mentioning that, although the five studies included in this review focused, at least partially, on the enhancement of JA, three of them included neither in the title nor in the abstract any keyword related to JA (Costa et al., 2015; Goodrich et al., 2012; Tapus et al., 2012); in these cases, JA keywords were concealed behind umbrella terms such as *social skills, communication skills* or *interaction skills*. Had the researcher –instead of the broad search that was conducted for Study 1 –conducted a specific search for papers with JA keywords, three of the five papers currently included would have been missed. Future studies on this topic should incorporate JA keywords on titles and/or abstracts of their publications.

4.1.4 Research design

Traditionally, ASD educational research have applied more SSDs due to the heterogeneity of participants' characteristics (Reichow, 2011). However, Study 1 showed that there is an important body of research that evaluates learning outcomes through group designs, and an increasing interest in conducting RCTs in the field. According to the results of the present review, the two studies that applied group designs are the most recently published ones (Costa el., 2015; Warren et al., 2015). However, the number of participants they included (i.e., eight and six respectively) is not big enough to conduct statistical analyses and draw conclusions on the effectiveness of the interventions. Also the fact that none of them included a control or comparison group, shows the lack of research strength. In the light of this, unless a researcher has the number of participants and resources required to carry out an adequate RCT, applying SSDs might be considered a better option.

Besides, the types of SSDs that have been used in the studies are not very strong either. Goodrich et al. (2012) applied an AB design to two participants with only two data collection points that did not allow to observe trends through conditions or to control threats to the internal validity of the study such as history (i.e., events that occur besides the intervention that may affect participants' performance). Tapus et al. (2012) applied an ABAC design to four participants with multiple data collection points that allowed to visually analyse shifts between adjacent conditions but did not yet allow to control for several threats like history. By applying multiple baseline or multiple probe designs, these constraints can be overcome; by measuring multiple baselines that are different in length and introducing the intervention at different time points, any changes in learning outcomes can be more accurately associated to the intervention effect. The reviewed paper of Cheng and Huang (2012) applied a multiple probe design and, compared to the other studies, has obtained more positive scores on the research rigour ratings. This demonstrates that choosing an appropriate research design (either SSD or group design) may help to get more research report rigour and strength and, as such, it might foster the development of EBP.

4.1.5 Setting

Choosing an adequate setting for conducting a TMI study is important. There might be cases in which technology cannot be moved away from laboratories or the intervention needs to be conducted in a specific place that is unknown to the participant. However, when possible, interventions should be implemented in real-world settings where children with ASD spend most time such as home or school (Kasari & Smith, 2013; Parsons & Kasari, 2013).

Although research literature calls for meaningful collaboration and involvement of the people who daily work and give support to individuals with ASD (Kasari & Smith, 2013), the interventions of the reviewed studies were implemented by unfamiliar people. Since teaching new skills to a child with ASD in a new environment by unfamiliar people minimise the likelihood of generalisation and maintenance of these skills, researchers in the field should carefully choose the place where participants are going to learn and who is going to teach them. The consideration of these two features will significantly contribute to the social validity of the study.

4.1.6 Country

Lack of ASD awareness, language constraints, limited access to technology or absence of available research funds are some reasons that could partly explain why previous ASD research studies have been mainly conducted in English speaking high-income countries (Zaroff & Uhm, 2012). This might also be the case for this review since three studies have been conducted in US and UK. However, it might not be safe to draw this conclusion with a review that has such small number of studies. In any case, the fact that the reviewed studies were conducted across four different countries and three different continents may indicate a wide interest. Because JA is a core skill to communicate in every culture (Mundy, 2016), researchers are encouraged to implement interventions that focus on this ability, in different places all around the world.

4.1.7 Year

Since JA difficulties in people with ASD were known long before most of the current technologies appeared, it is surprising that the first papers identified in this review were published in 2012. It is possible that some papers have been missed due to (a) publication bias (i.e., unpublished TMI studies that targeted JA in people with ASD), (b) an inability to locate them due to the search strategy conducted in this review or (c) not matching the inclusion criteria of this review.

Nevertheless, the results indicate that TMIs for JA in ASD form a recent interest. Since the use of technology with people with ASD is gradually increasing (Fletcher-Watson, 2014), it will not come as a surprise if studies focusing on JA also see an increase in the next few years. This growth might be facilitated by an easier access to different types of technology and a higher access to previous intervention experiences like the ones reviewed in the present study.

4.1.8 Journal

Since the enhancement of JA is targeted in many psychological and educational therapies, it would have been expected that interventions focusing on these skills would have been published in ASD and special needs journals, which are generally read by professionals. However, three of the five reviewed papers were published in journals that, at least partially, focus on computer science and technology. Considering this finding, future research on this topic should widen the search of studies into computer science and technology journals and databases.

It is worth mentioning that the research rigour and strength obtained by the reviewed studies does not seem to be related to the aim and focus nor to the IF of the journal where they have been published. Both ASD and non-ASD journals of high and low IF have published papers with weak research quality ratings.

4.2 EBP evaluation

The evaluative method applied has showed lack of rigour and the need to strengthen the studies in the field of TMIs for enhancing JA skills in individuals with ASD. Some of the limitations detected through the application of the quality indicators have been already discussed in previous sections of this study (e.g., lack of participant information and the use of non-real-world settings). Points that have not yet been addressed are mentioned in the following.

Concerning participant characteristics, one of the indicators that most studies disregarded is the description of the person(s) who implemented the intervention. In some of the reviewed studies, terms such as *the experimenter* or *the instructor* are used. However, their characteristics are not made explicit and researchers who may be interested in replicating the study might miss important information such as the background of the interventionist. Since this method considers that the ability to determine who did the intervention is a significant criterion, future studies are encouraged to provide this information. Including raters that are blind to the conditions and evaluating the procedural fidelity are also two important features that all of the reviewed studies omitted. Although these indicators are secondary, they contribute to the validity of the study and are therefore recommended to be considered in future studies.

With regard to the studies that used group designs, the absence of a control or comparison group and the use of small samples are their main limitations. Studies without comparison condition and that yield unreliable statistical conclusions due to small samples always receive unacceptable ratings. According to the evaluative method, if a study has one primary indicator rated as unacceptable, regardless of the rigour of the rest of the indicators, its strength will be rated as weak. Therefore, future research using group designs which seek rigour, should overcome these limitations.

No study calculated the effect size of the intervention. Although in this method the report on the effect size is only evaluated in studies with group designs, both SSDs and group designs should consider its calculation. One of the main reasons researchers are encouraged to provide an effect size is that this makes the studies eligible for meta-analytic reviews (Petticrew & Roberts, 2006). Meta-analysis is considered to be a powerful tool for jointly analysing the effect of a set of interventions with a common aim to conclude whether they have been effective or not. In order to do a meta-analysis, primary studies need to indicate the effect size (e.g., odds ratio, weighted mean differences) or, at least, to provide the data that is necessary for determining the effect size of the intervention (e.g., number of participants, arithmetic mean and standard deviation) (Botella & Gambara, 2002). The lack of this data may explain why there are only three meta-analyses in the field of TMIs for individuals with ASD (i.e., Alzrayer et al., 2014; Grynszpan et al., 2014; Sansosti et al., 2015). By increasing the research rigour and strength of the studies, effect size calculations will become more feasible and, consequently, there will be more chances for carrying out meta-analytic reviews in this research area. Generally, this could soon contribute to the emergence of the first TMIs that are evaluated by prestigious research synthesis organisations like the ones mentioned in the introduction of this study, and be published in NAC reports as established EBP.

Regarding the effectiveness of the interventions, all the studies claimed to be successful for almost all the participants included. This finding is in line with previous research that indicated that JA skills can be enhanced in children with ASD with appropriate interventions (Rogers & Dawson, 2010).

In the present work, Reichow et al.'s (2008) evaluative method has been chosen amongst many others for the reasons stated in the method section. Although the requirements for a study to be considered strong by this method might be too demanding, it is a suitable method for evaluating interventions that include individuals with ASD. Accordingly, the use of this method should be highly recommended not only for evaluating the quality of published studies but also to be used as a guideline for designing and implementing new research projects in the ASD field. However, the use of ITs have some particularities –as the lifecycle described by Herrera (2015) that has been presented in Chapter 1 (p. 94)–, which are not contemplated in the available EBP frameworks. These thoughts motivated the presentation of a panel session at the 2nd ITASD (Paris, 2014) in which Brosnan (University of Bath, UK), Grynszpan (Pierre et Marie Curie University, France), Goodwin (Northeastern University, US) and the researcher (Universitat de València, Spain) discussed the needs of EBPs in the field. As a result, these four researchers jointly with Mills (Research Autism, UK), Fletcher-Watson (University of Edinburgh, UK), and Herrera (University of Valencia, Spain) are, at the time of this writing, working on a project funded by the International Foundation of Applied Disability Research (FIRAH) for developing and implementing a specific EBP framework for ITs and ASD. Preliminary results are being presented at the 3rd ITASD, which is being celebrated in Valencia in July 2017.

4.3 Limitations

Most limitations of this study are related to the search strategy that was conducted for the systematic review and, therefore, are the same as in Study 1. One additional limitation of this study is the fact that there was no second rater for selecting the papers that targeted JA, extracting further information from the selected papers or applying the evaluative method on the five reviewed papers due to time and human resource restrictions. Then, no IOA scores were calculated. However, since this process has been followed in great scrutiny in Study 1 and the researcher was trained for applying Reichow et al.'s (2008) evaluative method before this study was developed, the possibilities of bias are limited.

5 Conclusion

The first purpose of this study was to systematically review the TMIs that have been implemented in the last 15 years to enhance JA skills in individuals with ASD. All the studies were conducted with males between 2 and 12 years old, in a variety of settings, across four different countries, and in the last five years. The robot is the technology item that was used the most. Interventions mainly focused on RJA skills and were published in five different journals with diverse scope and readership. The second purpose was the evaluation of the research rigour and strength of the studies reviewed to determine the level of EBP in the field. From the studies reviewed, no EBP was established. The lack of comparison conditions and small sample sizes are the main weaknesses of the studies that contributed to this. Results from this review indicate the importance and need of increasing the methodological rigour of primary studies. By using Reichow et al.'s (2008) evaluative method, the researcher demonstrates the potential of this tool for evaluating research rigour and strength, and for being used as a guideline for designing future studies in the field of TMIs in ASD.

Chapter 4

Study 3. Enhancing JA Skills in Children with ASD through an Augmented Reality-TMI

1 Introduction

As explained in Chapter 1 and recalled in Study 2, literature to date suggests that behavioural and JA targeted intervention studies can be effective in increasing IJA and RJA skills, partially contributing to the improvement of other critical developmental areas, including social and language skills such as social initiations, positive affect, imitation and spontaneous speech in children with ASD (Ferraioli & Harris, 2011; Kasari et al., 2006; Kasari et al., 2008; Kasari et al., 2010; Martins & Harris, 2006; Rocha et al., 2007; Taylor & Hoch, 2008; Whalen & Schreibman, 2003; Zercher et al., 2001). In this study, information on the participants' characteristics, the research design applied and the setting where these previous interventions were conducted, is described.

1.1 Features of previous intervention studies focusing on the enhancement of JA

Whalen and Schreibman (2003) applied a multiple baseline SSD in a laboratory to five 4-years old children using a naturalistic behaviour modification technique based on DTT and PRT components. The intervention consisted of three 25-minute sessions each day, three days a week for approximately 10 weeks. Mixed results for IJA (i.e., four of the five participants improved) and an increase in RJA were observed after the intervention. A follow-up of this study was conducted by Rocha et al. (2007), who also applied a multiple baseline SSD, but in a real-world setting which was led by parents, to three participants between 2 and 4 years old using PRT. After receiving at least 17 hours of intervention in 51 20-minute sessions, all participants demonstrated an increase in IJA and RJA.

Some years later, Ferraioli and Harris (2011) systematically replicated the intervention procedures described by Whalen and Schreibman (2003) for evaluating the effects of a sibling-mediated intervention conducted in the homes of four children between 3 and 5 years old. A multiple probe SSD was used and each participant received two or three 15-minute sessions per day, one or two times per week, completing between 32 and 37 sessions in seven to nine weeks. Findings indicated mixed results for IJA (i.e., three of the four participants improved) and an increase in RJA. Besides, Martins and Harris (2006), applied a multiple baseline SSD to enhance RJA skills in three children between 3 and 4 years old using reinforcement methods at school. Each participant went through 10-20 minute sessions, three times a week, finally receiving between 25 and 42 sessions. They found increase in RJA but no change in IJA, indicating that for improving IJA skills these may need to be explicitly targeted in an intervention. Further, using reinforcement plus prompting methods, Taylor and Hoch (2008) applied a multiple baseline SSD to three children between 3 and 8 years old; results indicated increase in both IJA and RJA in the three participants. Another intervention study (Zercher et al., 2001) applied a multiple baseline SSD to two children of 6 years old using modelling methods delivered by peers. After having conducted 30-minute weekly sessions for over 16 weeks, general increase in IJA and RJA was observed in the two children.

Other targeted JA interventions, such as JASPER, that have been integrated in a more comprehensive intervention programme targeting other developmental areas beyond JA, led to improvements in JA skills (Kasari et al., 2006; Kasari et al., 2010) as well as other principal related areas such as language development (Kasari et al., 2008). Firstly, Kasari et al. (2006) developed an intervention to be conducted 30 minutes daily for five to six weeks. Their RCT included 20 participants between 3 and 4 years old in the intervention group that, compared to the control group, improved in IJA and RJA. A follow-up of this study indicated that the IJA improvements were maintained over time (Kasari et al., 2008). Based on Kasari et al.'s (2006) intervention study, Kasari et al. (2010) evaluated the effects of a parents-delivered intervention that consisted of 24 sessions of 45 minutes to be conducted three times a week, in eight weeks. Their RCT included 19 participants between 2 and 3 years old in the intervention group that, compared to the wait-list control group, did not improve in IJA but did improve in RJA.

1.2 Relevant findings from Study 2

The fast development of ITs in the last years has triggered new approaches to enhancing JA in people with ASD. Study 2 has reviewed five TMI studies the aim of which was the enhancement of JA skills. Cheng and Huang (2012) applied a multiple probe SSD using the VR-based JASL system with three participants between 9 and 12 years old in a laboratory. After six 30- to 40-minute intervention sessions with one session per week, all participants improved their IJA and RJA skills. Goodrich et al. (2012) applied an AB SSD using the robot Troy with two participants of 3 and 8 years old who received 16 10-minute intervention sessions over a three-month period. Increases in IJA and RJA were observed. Tapus et al. (2012) applied an alternating treatment SSD using Nao the robot with four participants between 2 and 6 years old in a laboratory. Each participant went through two 15-minute sessions per day, from seven to 13 sessions, over a two-week period. Findings indicated mixed results for IJA and RJA (i.e., two of the four participants improved). Warren et al. (2015) applied a group design also using Nao with six participants between 2 and 4 years old who interacted with the robot for four sessions that took place in different days along a 30-day period in a laboratory. Results from this study indicated an increase in RJA. Finally, Costa et al. (2015) applied a group design using the robot KASPAR in a school with eight participants between 6 and 9 years old who received seven intervention sessions of 10 minutes. Findings revealed increased IJA and RJA.

Thus, these five TMI studies indicated improved performance after JA interventions in 21 of the 23 males of preschool and primary school age participants with ASD who were included in them. Therefore, these studies can be seen as promising attempts for addressing JA needs through novel TMIs. However, some limitations were identified in Study 2 for these studies, including a lack of availability of the HW and SW technology used. In addition, all five studies were rated weak based on Reichow et al.'s (2008) evaluative method due to a lack of rigour and strength.

1.3 Augmented Reality

Augmented Reality (AR) has been defined as a technology that combines the information one perceives from the real world with information generated by the computer in real time (Lee, 2012). AR technology's main advantages for individuals with ASD compared to other ITs are that threefold. Firstly, AR can be considered as tangible presence (Herrera, Jordan, & Vera, 2006) in that the moment-to-moment awareness of users with ASD in the process of perceiving and acting in the world is much more natural than other ITs such as VR where the reality is simulated. Secondly, AR includes body representation which can help individuals with ASD to perceive themselves and track their own movements contributing significantly to maintain body awareness (Herrera, Jordan, & Gimeno, 2006). Thirdly, since AR combines both real and virtual characteristics, it can be a useful tool for scaffolding generalisation of skills learned in a virtual world to the real world (Kientz et al., 2014).

AR technology has been previously used in combination with a variety of ITs including smartphones, mirror-based systems and Kinect sensors, with individuals with ASD for the improvement of different social communication and interaction skills. For instance, Escobedo et al. (2012) conducted an intervention study in which MOSOCO (i.e., a mobile assistive app that uses AR) was used by three children with ASD in collaboration with nine typically developing peers between 8 and 11 years old in a school for seven weeks; the results indicated that the intervention increased the children with ASD's quantity and quality of social interactions with their peers, including behaviours such as eye contact. More recently, Bai, Blackwell, and Coulouris (2015) used a mirrored view AR-TMI, in comparison to a non-TMI, to elicit pretend play in 12 children with ASD between 4 and 7 years old; the results demonstrated that there was a higher frequency and duration of pretend play in the AR condition than the non-AR condition. Finally, Bhattacharya et al. (2015) developed a set of Kinect-based AR games for enhancing social and motor skills. A nine-month-long intervention study was conducted in which these games were used by 18 students with ASD between 8 and 19 years old in a collaborative environment in a school; the intervention was effective for supporting initiation of social activities between peers, and in eliciting novel body movements.

Another Kinect-based AR system that has the potential to aid in the development of children with ASD is *Pictogram Room*: a set of educational video games which are based on ASD research –with the input of outstanding researchers in the field such as Jordan, and have been specially designed for enhancing a wide variety of skills including JA (Casas et al., 2012; Herrera et al., 2012). Although Pictogram Room's effects on JA have not been evaluated, this AR system has been found to be effective for enhancing sensory-motor skills in children with ASD in a school setting (Mademtzi, 2016). A group design with 10 participants (five in the intervention group and five in the control group) was used for this study. The findings indicated improvements in sensory-motor skills of the children who received the intervention.

1.4 Aim of this study

In the light of the previous, the current study aimed to explore the impact of Pictogram Room on the RJA skills of gaze following and pointing in children with ASD. To ensure the rigour and strength of the research report, recommendations derived from Study 1 and Study 2 (e.g., the application of an appropriate research design considering the number of participants) as well as Reichow et al.'s (2008) quality guidelines (see Appendix D) were followed throughout the study.

2 Method

2.1 Participants

Seven pupils with ASD and without visual difficulties of preschool and primary school ages were recruited from a mainstream public school located in Manises (Valencia) to participate in the study. Further information on the participants' characteristics is shown in Table 14.

The seven pupils attended a number of classes in a unit within the school that is called *communication and language*. This modality of schooling, which in other countries is known as *autism units* or *communication units*, is currently established in 38 mainstream schools (i.e., one unit per school) of the Valencian Community, as a result of an innovative initiative of the Valencian Education Government for supporting the special educational needs of pupils diagnosed with ASD and/or Language Disorder (APA, 2013). For a pupil to be accepted in this unit it is indispensable to have a formal ASD or Language Disorder diagnosis. With a maximum capacity of eight pupils, each communication and language unit is generally formed by (a) one teacher of speech and hearing who aims at pupils' communication, language and speech; (b) one special education teacher who uses the most adequate teaching and evaluation strategies to achieve the pupils' curriculum goals; and (c) one educator who takes care of pupils' needs such as hygiene routines, eating or transitioning.

Table 14. Characteristics of the seven participants in this study.

Participant	Gender	Chronological age (years, months)	DSM-5 (diagnosis)	GARS-2	SCQ	Leiter-R (IQ)
P1	Male	7, 10	ASD (Level 3) with intellectual and language impairment	111	15	63
P2	Female	8, 6	ASD (Level 3) with intellectual and language impairment	-	28	52
P3	Male	7, 4	ASD (Level 3) with intellectual and language impairment, with ADHD	100	32	-
P4	Male	6, 7	ASD (Level 2) with intellectual and language impairment	81	13	80
P5	Male	5, 1	ASD (Level 3) with intellectual and language impairment	96	18	70
P6	Male	5, 5	ASD (Level 3) with intellectual and language impairment, with ADHD	98	31	54
P7	Male	3, 6	ASD (Level 3) with intellectual and language impairment	87	12	77

The communication and language unit of the participating school (see a picture of this unit in Figure 10) was formed of seven pupils, one teacher of speech and hearing, one special education teacher and two educators.

Figure 10. Photo of the communication and language unit of the participating school.

The unit layout and the organization and administration of activities were based on the TEACCH program (Mesibov et al., 2005). Besides, six of the seven pupils (i.e., P1, P2, P3, P5, P6, and P7) carried an individual PECS communication book (Bondy & Frost, 1994) (for an example, see Figure 11) where they had all the PECS cards they needed to communicate with others. The first activity these six pupils performed as soon as they went to school every morning was to elaborate, with the help of their teachers, the schedule of the activities for that day. This consisted of a routine in which each pupil took from his/her PECS communication book the cards which represented the activities (i.e., one card representing one activity) they would do on that day as indicated by their teachers, including meals and recesses. Then, the pupil placed them on an individual PECS schedule board ordering from the top –the first activity of the day– to the bottom, the last activity of the day (see the participants' PECS schedule boards in Figure 12). The seventh pupil (i.e., P4) did not use PECS cards but verbal language with short sentences to communicate with others, to do the daily schedule routine and activities.

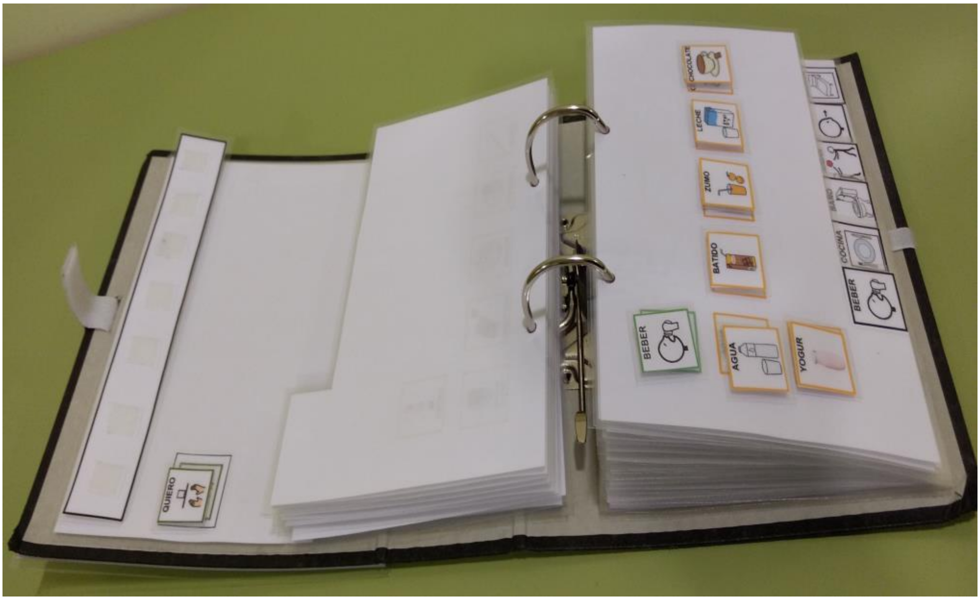


Figure 11. Sample of a PECS communication book.

Following the principles of inclusion (Ainscow, Booth, & Dyson, 2006), at different moments of the school day, these pupils left the communication and language unit to attend other classes (i.e., music, plastic arts, physical education) in their corresponding mainstream classrooms. The number of hours that the pupils spent in the communication and language unit and in the mainstream classroom varied according to each pupil's curriculum and special needs. They also enjoyed leisure time in the playground and lunchtime with peers with ASD, peers with other special educational needs and typically developing peers.

Figure 12. Participants' PECS schedule boards at the communication and language unit.

The two teachers of the communication and language unit participated in the study. On the one hand, the teacher of speech and hearing (hereafter referred to as "Teacher A") was a female of 28 years old who had a B.Sc. in Special Education with a major in speech and hearing, a B.Sc. in Speech Therapy and six years of experience in teaching pupils with ASD. On the other hand, the special education teacher (hereafter referred to as "Teacher B") was a female of 41 years old who had a B.Sc. in Special Education and 18 years of experience with pupils with ASD. Teacher A had multiple roles: she (a) taught the pupils how to play Pictogram Room, (b) was the pupils' playing peer in the sessions with Pictogram Room, and (c) participated in a number of assessments that were administered to the pupils. Moreover, Teachers A and B helped with the organization of each pupil's timetable and they provided valuable information regarding the pupils' special educational needs and abilities.

2.2 Setting and technology equipment

The room where all assessment and intervention sessions were conducted was located in the school and was called *audio-visual classroom* because it is where pupils used to watch movies and documentaries. It was spacious enough for interacting with an AR system, it had tables and chairs for the children and good light conditions (i.e., natural light that could be controlled with blinds). Regarding technology, the room was originally equipped with one Epson EMP-82 LCD Projector and one IDW (i.e., SMARTBoard™). To complete what was needed for the use of Pictogram Room, one PC with Windows 7, and one Kinect for Xbox were added. Additionally, another PC with Windows 7, one AKG UHF 40 pocket transmitter and stationary receiver, and three Samsung SCC-301P video cameras, statically located in different points of the room, were used for video-recording the sessions. See the final look of the room in Figure 13.

2.2.1 Pictogram Room

It is a free to download commercial SW (http://www.pictogramas.org) available in five languages (i.e., Spanish, English, French, Czech, and Bulgarian). It consists of four sets of video games called *The body*, *Positions*, *Pointing*, and *Imitation*. Each set contains multiple games that are ordered by difficulty and were developed to train different skills such as body awareness, proprioception, pointing, and imitation. There are 84 games in total. Most of them can be played either only by the student or collaboratively with the teacher or with a peer. Each game starts by asking the student and his/her teacher to be statically positioned in a natural posture for three seconds in front of two virtual doors (one for each player) to allow the Kinect calibrate their bodies at a specific distance of the screen. Players should keep that initial distance for the Kinect to adequately track them and ensure accurate performance during playtime.

Figure 13. Room arrangement: (a) board for the pupils to place the PECS cards, ($b_{1, 2, 3}$) video cameras, (c) projector, (d) IDW, and (e) Kinect.

The length of a game depends on the number of goals the player needs to achieve and the time it takes to achieve these goals. Once the player completes each game, a reward is displayed on the board and a scoring system pops up to allow the teacher to give a score to the student. The scores are as following: (0) if s/he did not complete it, (1) if s/he completed it with physical help, (2) if s/he completed it with verbal help, or (3) if s/he completed it on his/her own without help. This data can be recorded for later analyses (see Pictogram Room's sequence of play in Figure 14). All games can be adapted to each student's learning pace and they can also be personalized according to their visual (i.e., images, videos) and musical preferences through the aforementioned website, which automatically synchronizes with Pictogram Room.

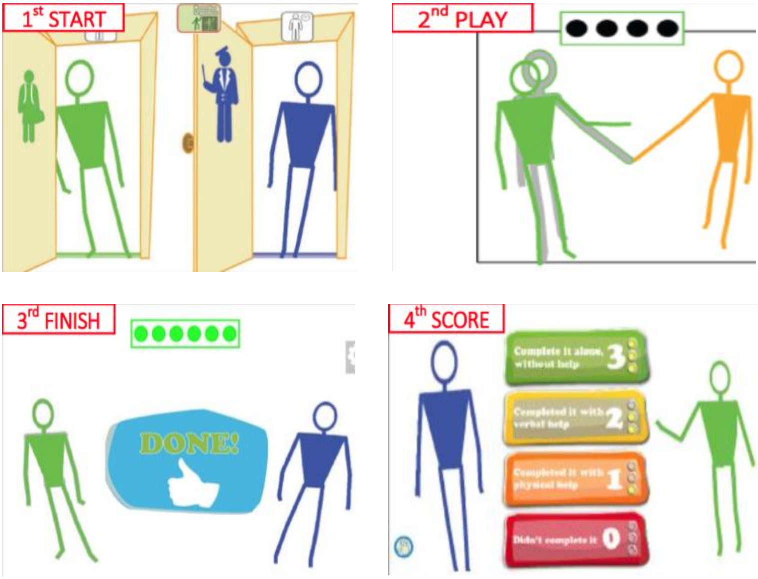


Figure 14. Pictogram Room’s sequence of play. Adopted from the pedagogical *guide for parents and tutors* that is available at http://www.pictogramas.org.

2.3 Assessments and materials

The standardised tools used for describing participant characteristics and evaluating JA skills, as well as the non-standardised materials used for evaluating JA skills during assessment sessions, are presented in this section.

2.3.1 Standardised tools for describing participant characteristics

DSM-5 diagnostic criteria for ASD (APA, 2013). Participants’ ASD diagnoses, based on the DSM-5 criteria that have been described in Chapter 1, were in the archives of the communication and language unit and were formally obtained by external clinicians before the start of this study. As mentioned previously, having a diagnosis of ASD or Language Disorder is a requirement for a child to be accepted in a communication and language unit.

GARS-2 (Gilliam, 2006). This is an instrument –the last version of which (i.e., GARS-3) has been described in Chapter 1– that assists teachers and clinicians in identifying and diagnosing ASD in individuals aged 3 years to 22 years and in estimating the severity level. This consists of 42 items describing (a) the stereotyped behaviour, (b) the communication, and (c) the social interaction of a person with ASD. A total score of 70 or higher indicates that the person possibly has ASD and a total score of 85 or higher indicates that the person is very likely to have ASD. Scores in GARS-2 were also in the archives of the communication and language unit and were formally obtained by external clinicians before the start of this study.

SCQ (Rutter, Bailey et al., 2003). The *Current* form of this scale, which focuses on behaviours observed during the most recent three months of a child's life, was administered to confirm the ASD diagnoses and severity levels that were previously obtained by external clinicians. A total SCQ raw score of 15 or higher is highly suggestive of ASD.

Leiter-R (Roid & Miller, 1997). This is a non-verbal intelligence and cognitive abilities test (*M*= 100 and *SD*= 15) –the last version of which (i.e., Leiter-3) has been described in Chapter 1– for individuals between 2 and 21 years old. The brief version of the test, which includes Visualization and Reasoning (VR) domains, was applied to get participants' intelligence quotient (IQ) scores. An IQ score below 85 suggests a below average cognitive ability and an IQ score below 70 is highly suggestive of ID.

2.3.2 Standardized tools for RJA skills assessments

ADOS-2 (Lord et al., 2012). Considering participants' characteristics, the RJA item of module 1 and the corresponding toy (i.e., remote-controlled toy animal) were used to measure RJA skills in this study. ADOS-2 procedures were followed and scores ranged from 0 (the student used the orientation of the evaluator's eyes as a cue to look towards the target, without the need for pointing) to 3 (the student did not orient to the object even when the object was activated).

ESCS (Mundy et al., 2003). In view of participants' ASD diagnoses and IQs, this scale was considered to be appropriate to measure their RJA skills. It includes an RJA module with an assessment in which the child sits in a chair in front of the evaluator with a table in between them. Four posters are placed on four different points related to the child's position: left, back left, right, and back right. Independent scores are obtained for left (L) and right (R) posters (hereafter referred to as "L/R RJA score") and back left and back right posters (hereafter referred to as "Behind RJA score"). The evaluator looks at one of the posters and children should respond by turning their head and looking in the same direction as the evaluator. The evaluator usually performs several trials. In this study, the researcher performed six trials for L/R RJA and six trials for Behind RJA with each pupil on each assessment session. Scores represent the coefficient between the number of trials in which the pupil presented RJA and the total number of trials (see an example of a room set-up for the ESCS in Figure 15).

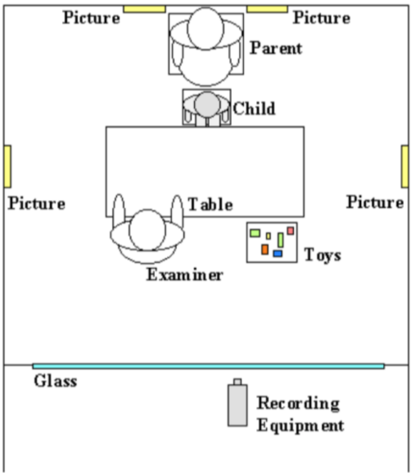


Figure 15. Example of a room set-up for the ESCS. Adopted from "A Manual for the Abridged Early Social Communication Scales" by P. Mundy, C. Delgado, J. Block, M. Venezia, A. Hogan, and J. Seibert, 2003, p. 3. Copyright 2003 by University of Miami.

2.3.3 Non-standardized tools for RJA skills assessments

Dummy. This consisted of a felt-based handcrafted face with an emotionally neutral expression and two fixed white circles simulating the eyes, with two movable black circles simulating the iris. The two irises were matched to the eyes with Velcro. This allowed the evaluator to move them around the eyes to show different points of gaze. The dummy had three holes (one for the head and two for the arms of the evaluator) to be worn as a costume (see Figure 16) This dummy was used in two assessments (i.e., *Which poster is the dummy looking at?* and *Which turtle is the dummy looking at?*) which are described in the design and procedures section.

Figure 16. The researcher wearing the dummy in one of the RJA skills assessments.

Posters. A set of A4 laminated posters with colourful images of cartoon characters (see Figure 17). These posters were used in two assessments (i.e., *Which poster is s/he looking at?* and *Which poster is the dummy looking at?*) which are described in the design and procedures section.

Figure 17. Sample of posters used in RJA skills assessments.

Turtles. Two blue and two green 4 x 6 x 8.5 cm plastic turtles with a simple mechanism based on a small wheel to be rotated for making them to walk short distances (see Figure 18). These turtles were used in two assessments (i.e., *Which turtle is s/he looking at?* and *Which turtle is the dummy looking at?*) which are described in the design and procedures section.

Figure 18. Wind-up mechanical turtles used in RJA skills assessments.

2.4 Design and procedures

A multiple baseline SSD (Kazdin, 1982) across three groups of three (Group 1) and two (Group 2 and Group 3) participants was conducted. The study lasted a total of 12 weeks and consisted of the following phases (see also Table 15):

2.4.1 Pre-baseline Phase (week 1)

2.4.1.1 One off assessments

SCQ and Leiter-R were administered to participants by the researcher, except for P3 who could not complete the Leiter-R assessment session. The scores obtained in the SCQ confirmed the diagnostic criteria of ASD (DSM-5) and the levels of severity (GARS-2) which were previously obtained for the participants by external clinicians, except for P2 who did not have such records. The Leiter-R scores informed of different levels of ID (i.e., borderline, mild and moderate) for the participants (see Table 14).

More precisely, P4 had the SCQ score below the established cut-off of 15 (i.e., 13), confirming the lower ASD severity that was previously described for him (i.e., level 2 instead of 3 in the DSM-5, and a GARS-2 score of 81). This participant, with a Leiter-R score of 80, was at the borderline of ID (i.e., between 70 and 85). Similarly, with an SCQ score of 12, P7 showed a lower ASD severity, which matched with the score of 87 obtained in the GARS-2. His Leiter-R score of 77 also indicated his borderline ID. On the contrary, P2 and P6 received Leiter-R scores which were between 40 and 55 (i.e., 52 and 54 respectively), indicating moderate ID. These two participants also received high scores in the SCQ (i.e., 28 and 31), indicating severe ASD levels, as shown in the GARS-2 score for P6 (i.e., 98). P1’s SCQ score of 15 did not match with the high score obtained in the GARS-2 (i.e., 111). However, his mild ID (i.e., Leiter-R score of 63) can account for that as well as for the level 3 of severity indicated in his ASD diagnosis (DSM-5). Finally, P5’s SCQ score (i.e., 18) confirmed the ASD diagnosis and severity level obtained previously and he showed in the Leiter-R, with a score of 70, to have a mild (or close to borderline) ID.

In view of the scores obtained, which showed that participants had below-average intellectual abilities ranging from borderline to moderate ID, these were considered throughout the study, especially for interpreting results accordingly. Tamarit (2007) indicated that IQ may not be a decisive factor for diagnosing ID, which is currently understood as a much more heterogeneous complex disorder that should not be seen as distinct but as part of ASD in many cases. However, he assumed that regardless of the disorders identified in a person, what is actually important for designing and implementing successful interventions is to take into account the individual characteristics (i.e., abilities and difficulties, strengths and weaknesses) including the information derived from IQ scores.

The researcher also went to the school in the first week of the study to observe the pupils' behaviours in the communication and language unit, mainstream classrooms and playground. In addition, she informally interviewed Teachers A and B to get useful information (e.g., interests, preferences) of the pupils for the customization of Pictogram Room.

2.4.1.2 Pre-assessments

ADOS-2 and ESCS tests were administered by the researcher to the seven participants. Besides, two non-standardized assessment called *Which poster is s/he looking at?* and *Which turtle is s/he looking at?* were conducted (see Figure 19). The researcher and the pupil were sitting opposite to each other and the teacher next to or behind the pupil. The researcher took two posters and positioned them next to her eyes, one on the left and one on the right. Then, she moved her eyes to look at one of them and Teacher A asked: "Which poster is she looking at?". The pupil could either name the content, point to the poster or take it. This task consisted of 10 trials in which the posters position and the gaze direction were randomly altered. Similarly, 10 more trials were performed using the turtles; the researcher held them next to her eyes, one on the left and one on the right and the Teacher A asked the question “Which turtle is she looking at?”. On the first five trials, the turtles had the same colour (two blue or two green), and on the subsequent five trials they had different colours (one blue and one green). Pupils were allowed to interact with the object of shared attention (i.e., observing the poster, making the turtle move) for a few seconds in between each trial. It should be noted that the questions used in these assessments were formulated based on the level of receptive language that Teacher A informed of the participants.

(a)

(b)

Figure 19. P7 during (a) *Which poster is s/he looking at?* and (b) *Which turtle is s/he looking at?* assessments.

Since the outcomes of the four assessments indicated that all pupils had difficulties in RJA –as will be further explained in the results section–, all seven participants were included in the study. Considering the time in which the multiple baseline SSD had to be applied (i.e., six weeks, from week 2 to week 7), three baselines of different duration could be included. Hence, participants were randomly assigned to three different groups: Group 1 was formed of three pupils (P1, P2 and P3), and Group 2 and Group 3 were formed of two pupils each (P4 and P5, and P6 and P7, respectively).

After this phase, the researcher visited the school three non-consecutive days a week for six weeks (i.e., from week 2 to week 7) for running one session with each participant a day resulting in three sessions per week per pupil.

2.4.2 Baseline Phase (weeks 2-4)

Baseline Phase had different duration for each group: Group 1 completed three sessions (week 2), while Group 2 and Group 3, completed six (weeks 2-3) and nine sessions (weeks 2-4), respectively. This phase consisted of evaluating the pupils' performance in two assessments called *Which poster is the dummy looking at?* and *Which turtle is the dummy looking at?* that lasted around 15 minutes: the researcher was wearing the dummy costume and followed the same procedure as in the *Which poster is s/he looking at?* and *Which turtle is s/he looking at?* assessments but randomly alternating dummy's gaze direction and the teacher asked the question "Which poster is the dummy looking at?" or "Which turtle is the dummy looking at?" (see Figure 20).

2.4.3 Learning Phase (week 3-5)

The purpose of this phase was to show and teach the participants how to play Pictogram Room. This consisted of three sessions for all groups. Thus, Group 1 went through the Learning Phase in week 3, while Group 2 and Group 3 went through it in weeks 4 and 5, respectively. This phase consisted of 30-minute sessions that included two parts: the familiarisation with Pictogram Room (15 minutes) plus *Which poster is the dummy looking at?* and *Which turtle is the dummy looking at?* assessments that have been described in the Baseline Phase (15 minutes).

(a) 

(b) 

Figure 20. P7 during (a) *Which poster is the dummy looking at?* and (b) *Which turtle is the dummy looking at?* assessments.

The familiarisation part became the first encounter with Pictogram Room and in order to facilitate the learning process, pupils used a very motivating and relatively easy game called *Touch*[1], which belongs to *The body* set of video games and does not focus on the practice of JA skills. The pupils played individually in the company of Teacher A while she was providing instruction and support. They saw their live images reflected on the board (see Figure 20). This game consisted of one static window (in level 1), one moving window (in level 2), one fast-moving window (in level 3) and one moving window surrounded by other distracting stimuli (in level 4). When the player touched the window, it opened and showed

[1] *Touch* is actually a group of four games, each of them with their final reward and scoring system. Since they are very similar and only differ in the level of difficulty, this has been considered as one game with four different levels (level 1-4) in this study. However, the reward and the corresponding score were still administered to the participants after each level was mastered.

his/her favourite video for a few seconds. After six successful trials, which were indicated with green circles on the top of the screen (see Figure 21), the level was mastered. Then, the researcher gave a score according to player's performance. When level four was reached, the game was completed. Participants played as many level games as they could during each session ensuring that all of them entered in level 4 by the third session.

Figure 21. P5 playing level 1 of Touch game in Pictogram Room with Teacher A during Learning Phase.

2.4.4 Intervention Phase (week 4-7)

Intervention Phase consisted of six sessions for all groups. Thus, Group 1 went through the Intervention Phase in weeks 4-5, while Group 2 and Group 3 went through it in weeks 5-6 and 6-7, respectively. This phase consisted of 30-minute sessions that included two parts: the intervention with Pictogram Room (15 minutes) plus the *Which poster is the dummy looking at?* and *Which turtle is the dummy looking at?* assessments that have been described in the Baseline Phase (15 minutes). The intervention with Pictogram Room consisted of the use of a game called *Gaze following*[2], which includes four levels of difficulty, belongs to the *Pointing* set of video games and focuses on the practice of JA skills. The pupil again played individually in the company of Teacher A while she was providing instruction and support. They saw their skeletons –instead of their live images– reflected on the board (see Figure 22): the teacher was grey and the pupil was green.

Figure 22. P2 playing level 4 of Gaze following game in Pictogram Room with Teacher A during Intervention Phase.

This game consisted of a virtual child's face with two big eyes that appeared surrounded by two (in level 1) or four (in levels 2-4) closed windows. The virtual child then pointed to and looked at (in levels 1-2), or just looked at (in levels 3-4) one of the windows. The teacher then asked the player: "Which window is the child looking at?". If the player touched the window that the virtual child was looking at, the window opened and showed his/her favourite video. If the player touched any other window, an unpleasant sound was produced and all the windows were gone in order for another trial to be offered. After four successful trials,

[2] *Gaze following* is actually a group of four games, each of them with their final reward and scoring system. Since they are very similar and only differ in the level of difficulty, this has been considered as one game with four different levels (level 1-4) in this study. However, the reward and the corresponding score were still administered to the participants after each level was mastered.

which were indicated with circles on the top of the screen (see Figure 21), the level was mastered. Then, the researcher gave a score according to player's performance. When level four was reached, the game was completed. Participants played as many level games as they could during each session controlling that all participants entered in level 4 by the fifth session.

2.4.5 Post-intervention Phase

2.4.5.1 Post-assessments (week 8)

The same procedure as in Pre-assessments was followed for administering the ADOS-2, the ESCS and *Which poster is s/he looking at?* and *Which turtle is s/he looking at?* assessments.

2.4.5.2 Follow-up assessments (week 12)

One month after the intervention finished, the *Which poster is s/he looking at?* and *Which turtle is s/he looking at?* assessments that have been described in the Pre-assessments were administered once to all participants on the same day and the *Which poster is the dummy looking at?* and *Which turtle is the dummy looking at?* assessments that have been described in the Baseline Phase were administered to all participants twice, once per day each for two non-consecutive days.

2.5 External and internal validity controls

A number of factors to reduce to the extent possible the threats to the external and internal validity of this study were considered and are presented in this section.

2.5.1 Research design

A multiple baseline SSD was implemented for controlling the participants' developmental maturation and exposure to the researcher and the intervention setting. This research design also allows for the assessment of several target behaviours simultaneously to test the effectiveness of an intervention.

Table 15. Description of the phases of the study.

Phase of the study	**Group (1-3)**	**Week (1-12)**	**Sessions (1-9)**	**Assessments**	**Pictogram Room games**
Pre-baseline Phase					
One off assessments	1-3	1	1	SCQ, Leiter-R	
Pre-assessments	1-3	1	1	ADOS-2, ESCS, *Which poster is s/he looking at?*, *Which turtle is s/he looking at?*	
Baseline Phase	1 2 3	2 2-3 2-4	3 6 9	*Which poster is the dummy looking at?*, *Which turtle is the dummy looking at?*	
Learning Phase	1 2 3	3 4 5	3 3 3	*Which poster is the dummy looking at?*, *Which turtle is the dummy looking at?*	Touch
Intervention Phase	1 2 3	4-5 5-6 6-7	6 6 6	*Which poster is the dummy looking at?*, *Which turtle is the dummy looking at?*	Gaze following
Post-intervention Phase					
Post-assessments	1-3	8	1	ADOS-2, ESCS, *Which poster is s/he looking at?*, *Which turtle is s/he looking at?*	
Follow-up assessments	1-3	12	2	*Which poster is the dummy looking at?*, *Which turtle is the dummy looking at?*, *Which poster is s/he looking at?*, *Which turtle is s/he looking at?*	

Intervention trends can be easily identified for each child and within subject variability can be measured, which is highly desired when intervening to individuals with special educational needs due to their heterogeneity.

2.5.2 Social significance

The social significance of the intervention was initially evaluated through a brief questionnaire addressed to participants' parents, teachers, psychologists, and the school head (see Appendix E). This questionnaire included questions related to the importance given to JA skills and the potential given to ITs as intervention tools for individuals with ASD. They all supported that JA skills were crucial for learning processes and acquisitions. More precisely, Teachers A and B reported a few attempts for enhancing children's JA through reinforcement-based methods (e.g., if the pupil followed the teachers' gaze by pointing to the target object, the pupil would get a reward). However, they were no longer specifically teaching JA because the method was not engaging enough for keeping the pupils focused and consequently no JA improvements were observed. Parents, teachers, psychologists and the school head believed that the use of ITs such as AR could facilitate the improvement of JA skills.

2.5.3 Intervention criteria

Randomly chosen typically developing peers were assessed once following the same procedures described for *Which poster/turtle is s/he looking at?* and *Which poster/turtle is the dummy looking at?* assessments to establish the starting point that would be desirable for each child's age. All children succeeded in all assessments getting a full percentage of correct responses on the first trial.

2.5.4 Use of Pictogram Room

Within Pictogram Room games, it was controlled that the unpleasant sound that was displayed after participants gave a wrong response (i.e., did not touch the target window) was not attractive for them (i.e., it was a common quiet sound) so they were not tempted to respond intentionally wrong to hear it. This was checked by observing that none of the participants touched the wrong window repeatedly across trials.

Participants never used Pictogram Room (or any other AR system) before this study started so they could not be influenced by previous experiences. Another control that was considered is that they were not given the option to play with Pictogram Room beyond the study sessions until this was over after week 12. Besides, no other specific intervention program for enhancing JA skills was implemented in the school, and the same holds for the therapy centres where all participants received behavioural interventions during the time this study was conducted. In this way, the learning outcomes of this study could be more adequately associated to the six intervention sessions conducted within the study.

2.5.5 Selection of materials

The cartoon characters presented in the posters were familiar to the pupils but their favourite ones were not used for avoiding impulsive choices based on their preferences. In this regard, two same-coloured turtles were used for ensuring that participants did correctly understand the actual meaning of *Which poster/turtle is she/the dummy looking at?* and that they did not make personal choices but they selected the target they thought was the correct one. In this regard, as explained in a previous section, the questions addressed to the participants in the assessments were carefully chosen together with Teacher A according to the participants' language abilities in order to facilitate their comprehension. No additional visual supports were used as Teacher A did not consider it necessary.

2.5.6 Length of the study

The length of the study –eight weeks without the follow-up assessments– was chosen based on the number of consecutive weeks the pupils attended school without holidays that could interrupt the implementation of the intervention and, most probably, bias the study outcomes.

2.5.7 Fidelity of the study

The researcher was present in all the study sessions ensuring the fidelity of the implementation of the intervention and providing continuous technical as well as educational support.

2.5.8 Familiarisation

The researcher went to school several days and spent long hours each day at the communication and language unit before this study started for getting to know the teachers, educators and pupils, and vice versa. This would allow the pupils to feel comfortable throughout the sessions of the study. Besides, information about children's interests and preferences (e.g., cartoon characters, videos, songs) was obtained from Teachers A and B. This facilitated, for instance, the development of appropriate rewards for the intervention sessions with Pictogram Room. Furthermore, valuable information on pupils' sensory and time management issues was provided by Teachers A and B. For example, the volume of Pictogram Room games was significantly turned down for P4 who had auditory hypersensitivity. A digital clock was also displayed on an iPad to visually remind the pupils throughout each session how long they had left.

2.5.9 Further adaptations

Two additional aspects that were considered due to the impact these could have on pupils' comfort and performance were the anticipation of each study session and the transitioning from the communication and language unit to the audio-visual classroom before each study session. For this purpose, two new PECS cards were added to the PECS communication books of P1, P2, P3, P5, P6 and P7: one card was the researcher's photo (including her name) and another card was a picture representing Pictogram Room (see Figure 23).

Each session with the researcher was anticipated as follows: the pupil placed the PECS card of the researcher's photo in his/her PECS schedule board. When the session was about to start, the pupil took the card from the schedule board, s/he walked to the audio-visual classroom and placed the card on a board that was located at the entrance door of the audio-visual classroom (see *a* in Figure 13). Once the session with the researcher was over, the pupil took the card from the board, walked back to the communication and language unit and placed the card into the finished box. Each session with the researcher and Pictogram Room had the same structure with the addition of the Pictogram Room card on the PECS schedule board.

With regard to transitioning, each child was accompanied by Teacher A, Teacher B, one educator or the researcher from the communication and language unit to the audio-visual classroom and vice versa, while the pupil was holding the PECS card(s) in a hand. Pupils also carried over their shoulders their PECS communication books and had them available –placed on a table or chair at within reach distance– throughout each session for them to be able to communicate anytime in case of need.

Figure 23. PECS card representing Pictogram Room.

2.5.10 Blindness

Teachers A and B were informed about the general purpose of the study but they were blind to the research design applied. More importantly, Teacher A was asked to not reinforce pupils' right answers and to not correct errors during assessments. In addition, two independent blind raters (i.e., undergraduate education students) received training by the researcher on the measured variables. Both coded all the assessment video recordings and IOA and Cohen's Kappa coefficients were calculated.

2.6 Ethics statement

The current study has been designed and implemented following the standards of the ethical commission for the empirical research with humans of the Universitat de València. This study also abides by the British Educational Research Association (BERA, 2011) and the British Psychological Society (BPS, 2010) ethical guidelines. Prior to the study, a one-hour meeting was arranged at the school in which the researcher explained to parents, teachers and the head of the school the purpose of the study and methods applied. By the end of the session, one of the parents of each child signed an informed consent form for their participation (see Appendix F for the form).

2.7 Data preparation and analysis

2.7.1 Operationalization of the measured variables

All measured variables are presented in Table 16. The first variable (i.e., v1) refers to the participants' performance within Pictogram Room games. As explained in the design and procedures section, each game had four levels and one score was given to the participant after each level was achieved. Since each participant could achieve a number of levels, and some could even complete games more than once within the same session, each participant obtained many scores in each session. The score that was given to v1 was the lowest obtained by the participant across all the level games played on that session.

Table 16. Operationalization of measured variables.

Variable	Assessment tool	Assessment unit	Scoring system	Scoring system description
v1	Pictogram Room games	General performance	0-3	0= player did not complete the level game 3= player completed the level game on his/her own
v2	*Which poster is the dummy looking at?*	Percentage of correct responses	0%-100%	0%= 0 correct responses in 10 trials 100%= 10 correct responses in 10 trials
v3	*Which turtle is the dummy looking at?*	Percentage of correct responses	0%-100%	0%= 0 correct responses in 10 trials 100%= 10 correct responses in 10 trials
v4	*Which poster is s/he looking at?*	Proportion of correct responses	0-1	0= 0 correct responses in 10 trials 1= 10 correct responses in 10 trials
v5	*Which turtle is s/he looking at?*	Proportion of correct responses	0-1	0= 0 correct responses in 10 trials 1= 10 correct responses in 10 trials
v6	ESCS	L/R RJA Behind RJA	0-1	0= 0 correct responses in 6 trials 1= 6 correct responses in 6 trials
v7	ADOS-2	RJA	0-3	0= the lowest RJA level 3= the highest RJA level

2.7.2 Data analysis

Scores obtained for v1 were visually analysed to observe performance improvement within Pictogram Room games throughout the study. IOA coefficients were calculated for v2-v7 as the number of agreements between the two raters divided by the number of agreements plus the number of disagreements. Cohen's Kappa was also calculated for v2-v7 by measuring the agreement between the two raters, subtracting agreement due to chance (Cohen, 1960). IOA can range from 0 to 1, with values higher than .80 indicating good IOA. Kappa can range from -1 to 1, and values higher than .70 indicate good inter-rater reliability. Besides, *Percentage of All Non-Overlapping Data* (PAND) (Parker, Hagan-Burke, & Vannest, 2007) and Pearson *Phi* coefficients were calculated for v2-v3 using IBM SPSS Statistics 22.0 to assess effectiveness of the intervention, given that these statistical techniques are suitable for identifying significant differences between scores obtained in baseline and intervention phases. Scores obtained for v4-v5 at pre-, post- and follow-up assessments and scores obtained for v6-v7 at pre- and post-assessments were compared to evaluate generalisation of the target skills. Additionally, Reichow et al.'s (2008) single subject research quality indicators (see Appendix D) were applied to analyse the research report rigour and strength.

3 Results

The seven pupils participated throughout the study. However, P3's results were not included in the analyses because most of his assessment and intervention sessions were interrupted due to the presence of significant attention deficits and hyperactivity, and continuous behavioural outbursts. Thus, results are shown for the other six participants.

3.1 Performance improvement within Pictogram Room games

Scores that were given to the participants within Pictogram Room after they completed each game level showed that they significantly improved their performance as the study went along. Scores for the six participants are shown in Figure 24. They were all engaged in the games since the first session so they completed all the level of the games they played. However, they needed physical or verbal support to complete the games in the first couple of sessions. Particularly, P5 needed significant physical support at the beginning because instead of looking at the screen (i.e., AR environment), he was looking around for finding the stimuli in the real world. However, at the second session of the Intervention Phase he performed well without physical support and mastered playing independently in the three last sessions. Additionally, P5 and P6 required significant physical support in the first sessions because instead of keeping their initial position they tended to go to the IDW to touch the stimuli on it. Towards the end of the Intervention Phase, all pupils except P6 performed all the levels of the games independently.

Although the performance within Pictogram Room was not used as a measure of RJA improvement, it is worth mentioning that all participants responded to JA successfully in the last three sessions of the Intervention Phase by touching the window that the virtual child was looking at, without any support from Teacher A.

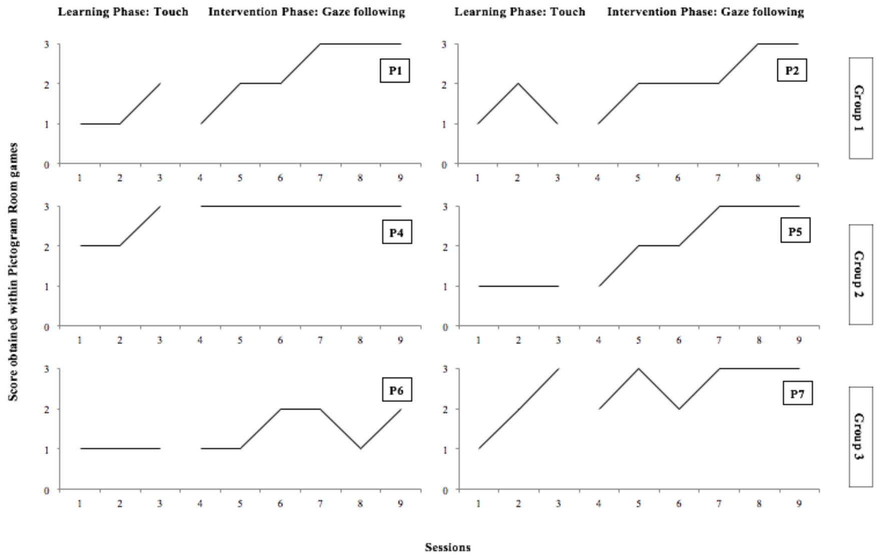


Figure 24. Participants' scores within Pictogram Room games.

3.2 Effectiveness of the intervention

The intervention was effective for all participants in terms of enhancing their RJA skills. At later stages of the Intervention Phase participants followed the dummy's gaze and they pointed to the target object of shared attention (i.e., poster or turtle) between the dummy and the participant. IOA and Kappa coefficients for v2 and v3 were 1, which shows a perfect inter-rater reliability. Results have been plotted and are shown in Figure 25.

Participants responded in a very similar way to both v2 and v3 throughout the study. Therefore, participants did not perform differently when they had to gaze follow and point to one of the two objects when they were different (i.e., posters in v2) compared to when the two objects were the same (i.e., turtles in v3).

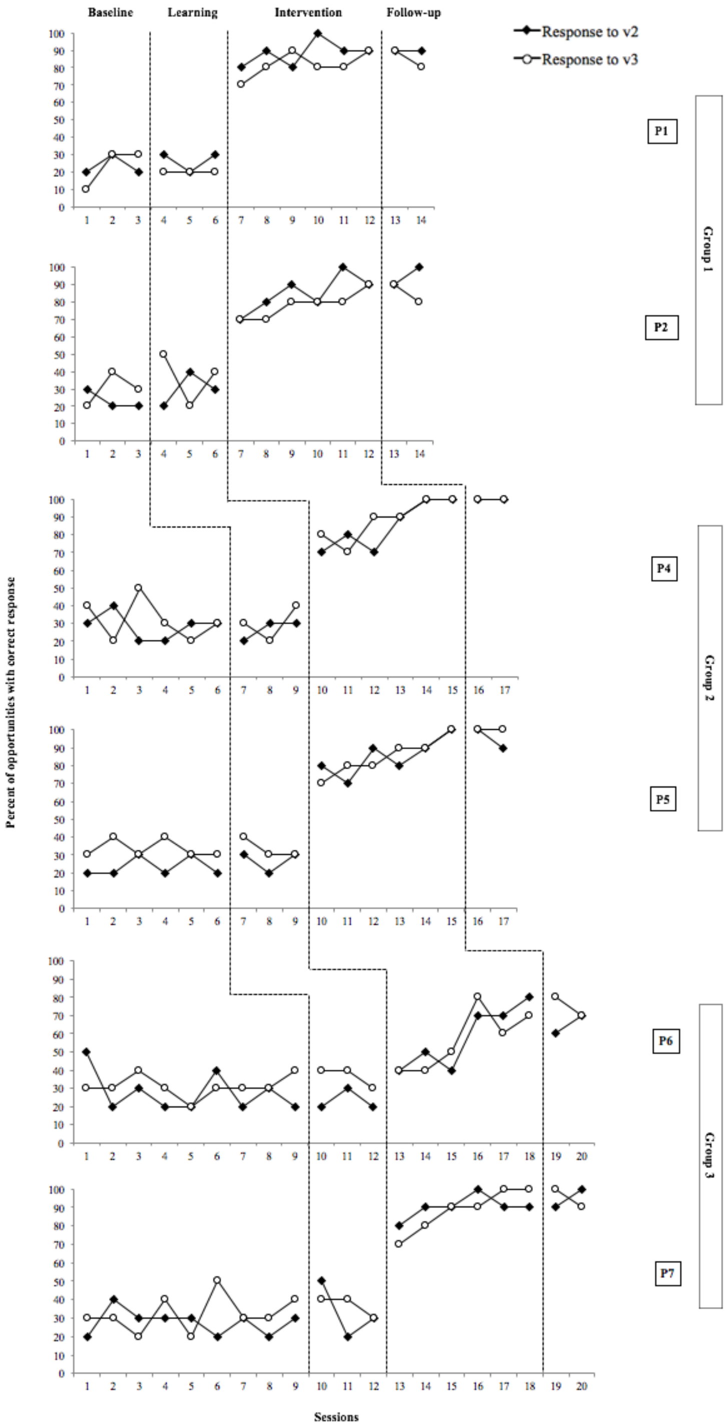


Figure 25. Participants' performance in v2 and v3 throughout the study.

Also, no important differences were found when they had to gaze follow and point to one of two turtles when they had a different colour compared to when they had the same colour. No improvements were observed in any of the participants during Baseline Phase or Learning Phase for any of the two variables. When the intervention with Pictogram Room was introduced (Intervention Phase), notable improvements in RJA were observed. The four participants from Groups 1 and 2, and P7 from Group 3 experienced significant improvements since the first session of the Intervention Phase and they did not present any overlapping point between Baseline and Learning Phases, and Intervention Phase. However, P6 did not show clear improvements until the fourth intervention session, presenting a few overlapping points between phases. P1 and P2 mastered pointing to the right poster after four and five sessions, respectively, but none of them mastered pointing to the right turtle. P4 mastered pointing to the right poster and the right turtle after five sessions. P5 mastered both variables in the last intervention session. P7 was able to master pointing to the right poster and the right turtle after four and five sessions respectively. P6 mastered neither pointing to the poster nor to the turtle. At follow-up assessment, all six participants maintained the ability to gaze follow the dummy and point to the target object that they got towards the end of the Intervention Phase.

An overall PAND of 98% and 96% were obtained for v2 and v3, respectively. This shows that the intervention was highly effective (PAND > 90%) for enhancing the abilities of gaze following and pointing to the target object in six children with ASD. Besides, Pearson *Phi* coefficients of 0.96 ($p < .01$) and 0.92 ($p < .01$) were obtained for the same variables. This indicates a strong positive association (*Phi* > .70) between the intervention and the learning outcomes.

3.3 Generalisation of RJA skills

RJA improvements that were found in following dummy’s gaze were generalized to real gaze (see results for v4-5 in Table 17).

Table 17. Pre-, post- and follow-up measures, IOA and Kappa scores for v4-7.

	Participant	V4			V5			V6: ESCS				V7: ADOS-2	
		Poster			Turtle			L/R RJA		Behind RJA			
		Pre	Post	F-up	Pre	Post	F-up	Pre	Post	Pre	Post	Pre	Post
Group 1	P1	.30	.90	.90	.30	1	1	.17	.83	0	.67	2	2
	P2	.30	1	1	.20	1	1	.33	.83	.17	.67	2	1
Group 2	P4	.30	1	1	.30	1	1	.67	1	.50	1	1	0
	P5	.20	1	.90	.30	.90	.90	.50	.83	.17	.83	2	2
Group 3	P6	.40	.80	.90	.20	.80	.70	.17	.67	0	.33	3	3
	P7	.30	1	1	.20	1	1	.33	1	.33	.83	2	1
IOA		1			1			.97				.92	
Kappa		1			1			.94				.88	

The comparison between pre- and post-assessments revealed that all participants improved at following the researcher's gaze and pointing to the target posters and turtles. Follow-up assessments indicated that improvements were maintained a month later. The L/R RJA scores in ESCS obtained at pre- and post-assessments (see results for v6 in Table 17) also indicated improvements in all pupils' RJA skills. The Behind RJA scores showed generalisation to correctly gaze follow and point to the target object when they were placed behind the pupil. Finally, RJA scores in ADOS-2 obtained at pre- and post-assessments (see results for v7 in table 17) revealed that three of the six participants performed significantly better after the intervention: P2 and P7 followed the researcher's pointing and they successfully looked at the target object; P4 used the orientation of the researcher's eyes as a cue to look effectively at the target object. IOA and Kappa scores indicated a perfect inter-rater reliability for v4-5 and a good inter-rater reliability for v6-7 (see Table 17).

3.4 Research report rigour and strength

All in all, this study is considered rigorous according to Reichow et al.'s (2008) evaluative method (see Table 18). Since all primary quality indicators were rated high, and there was evidence for five of the six secondary quality indicators, this became a strong research report.

Table 18. Research report rigour rating.

Rigour rating											
Primary quality indicators						**Secondary quality indicators**					
PART	IV	DV	BSLN	VIS AN	EXP CON	IOA	KAP	FID	BR	G/M	SV
H	H	H	H	H	H	Y	Y	N	Y	Y	Y

Note. PART: participant characteristics; IV: independent variable; DV: dependent variable; BSLN: baseline condition; VIS AN: visual analysis; EXP CON: experimental control; IOA: interobserver agreement; KAP: Kappa; FID: fidelity; BR: blind raters; G/M: generalisation and/or maintenance; SV: social validity; H: high quality; A: acceptable quality; U: unacceptable quality; Y: there is evidence; N: there is no evidence. Rating form adapted from "Development, Procedures, and Application of the Evaluative Method for Determining Evidence-Based Practices in Autism," by B. Reichow, 2011. In B. Reichow, P. Doehring, D. V. Cicchetti & F. R. Volkmar (Eds.), *Evidence-based practices and treatments for children with autism,* p. 38. Copyright 2011 by Springer Science+Business Media.

4 Discussion

4.1 Results summary

The results obtained in this study have shown that the implemented AR-TMI has been effective for all of the six participants included. More precisely, the six pupils improved their abilities for following the gaze of a dummy and pointing to the object that the dummy was looking at. After the intervention, the six pupils demonstrated generalisation of the skills to follow the researcher's gaze and pointing to the target object she was looking at. Additional pre- and post-assessments also showed generalisation of RJA skills to other novel situations. Maintenance of the skills was observed one month after the intervention.

4.2 Results compared to previous studies

Overall, the pupils who participated in this study showed that children with ASD may have difficulties in gaze following and pointing prior to the intervention, but they can also improve these skills; these abilities have been evidenced not only within Pictogram Room but also in all the scores obtained in the assessments that have been conducted beyond the piece of technology (i.e., *Which one is the dummy looking at?*, *Which one is s/he looking at?*, ESCS and the RJA item of the ADOS-2). These findings support theoretical studies that affirm that JA constitutes a difficulty for many individuals with ASD that can be effectively addressed with appropriate interventions (e.g., Mundy & Crowson, 1997; Mundy et al., 2007). Furthermore, the findings of the present study are in line with previous studies that indicated that RJA skills can be enhanced in children with ASD through behavioural interventions such as PRT (Ferraioli & Harris, 2011; Rocha et al., 2007; Whalen & Schreibman, 2003), reinforcement and prompting methods (Martins & Harris, 2006; Taylor & Hoch, 2008), modelling methods (Zercher et al., 2001), and targeted JA interventions such as JASPER (Kasari et al., 2006; Kasari et al., 2008; Kasari et al., 2010).

4.3 Advantages of the AR-TMI used

The AR-TMI used has several advantages compared to previous intervention programs.

4.3.1 Length

The length is shorter than that of other interventions which are either very intense (i.e., many sessions of long duration in a few weeks) or spaced (i.e., a few hours of intervention delivered throughout many weeks). The present AR-TMI has been effective in six children after six 15-minute intervention sessions. Therefore, this is a short effective targeted RJA intervention that is suitable for situations in which children’s or interventionists’ time is limited.

4.3.2 Ecological validity

Another important advantage of the present intervention is that Pictogram Room is an easy-to-learn system that can be used by anyone (e.g., teachers, clinicians, parents) who wants to teach RJA skills without the necessity for going through long and sophisticated training programmes. This advantage also facilitates the implementation of the same intervention across people with different roles (e.g., teachers, clinicians, parents) across settings (e.g., school, therapy centre, home) increasing the chances for practising and generalising RJA skills. Literature has highlighted the importance of implementing JA interventions in children with ASD which are delivered by parents (Kasari et al., 2010; Rocha et al., 2007), siblings (Ferraioli & Harris, 2011) or peers (Zercher et al., 2001) due to the need for more ecologically-valid interventions. For this purpose, in these previous studies a number of parents, siblings and peers were trained in specific teaching methods such as ABA for which they invested time and effort in order to become autonomous for delivering interventions effectively.

4.3.3 Availability and accessibility

Another advantage of this intervention study compared to the previous TMIs that have been reviewed in Study 2 (i.e., Cheng & Huang, 2012; Costa et al., 2015; Goodrich et al., 2012; Tapus et al., 2012; Warren et al., 2015) is the availability of the HW and SW that are needed for its implementation. Pictogram Room only requires HW that is commercially available and relatively inexpensive if it is compared to other technologies such as sophisticated robots. Besides, most of the required HW (e.g., a PC, a projector) is often available at many schools at least in developed countries. Furthermore, the SW is free to download in different languages, being more accessible to people with different cultural backgrounds. All the above-mentioned advantages might make Pictogram Room a more eligible system for being included as a school activity. Moreover, this AR-TMI has been designed to be delivered by one interventionist (e.g., teacher, mother) in one-to-one play sessions, as most previous behavioural interventions which principally focused on one-to-one sessions formed by the interventionist and the person with ASD. Thus, this TMI intervention allows teaching while dealing with the AR system, not requiring further personal resources. This is an advantage compared to what it has been found in previous TMI studies in which the technology necessarily had to be led by researchers to deliver prompts and respond according to children's behaviours (Costa et al., 2015; Goodrich et al., 2012).

4.3.4 Engagement

Furthermore, six children were engaged in the intervention sessions, most probably due to the attraction they felt towards the use of Pictogram Room. This fact could have benefited their attention span in task facilitating, therefore, the learning process. This finding may contribute to the widespread belief that the participants' engagement is an important condition that leads to better learning outcomes for individuals with ASD (Rogers & Dawson, 2010). There are various reasons why the use of Pictogram Room has been so engaging for all of the six participants. Firstly, all the stimuli were presented visually with reinforcing audio outputs, and verbal language was minimally used. The consideration of these features is in line with previous studies and intervention methods that highlight the importance of using visual stimuli and minimising the use of complex verbal language with individuals with ASD (e.g., Grandin, 2006; the TEACCH approach, Mesibov et al., 2005; Peeters, 2008). Secondly, the stimuli were personalised for each participant with their favourite pictures, videos and songs. This echoes other evidence-based intervention methods which indicate the relevance of building the interventions on each child's preferences and interests because this facilitates learning outcomes (e.g., ESDM, Rogers & Dawson, 2010; PRT, Koegel, Koegel, Harrower et al., 1999; Koegel, Koegel, Shoshan et al., 1999). Last but not least, as there was no specific timing for completing the games, participants could play according to their own pace and rhythm. Each session with Pictogram Room was set with a specific duration (i.e., 15 minutes) as the TEACCH approach (Mesibov et al., 2005) and other books on how to teach individuals with ASD (e.g., De

Clercq, 2012; Jordan & Powell, 1995; Peeters, 2008) recommend. However, given that each child has his/her own pace and it was not the number of game levels completed but that they learnt while playing that mattered, no maximum time was set for each level game to be completed. Literature indicates that many children with ASD might have gone through many unsuccessful experiences at school and might need more time to build self-confidence (Jackson, 2002). By giving them the time they need for completing an activity with success, frustration and other unwanted emotions may appear less often, increasing the engagement opportunities and promoting learning outcomes (Jordan, 1999).

4.4 Findings to consider in future research

Although six children were engaged in the sessions with Pictogram Room, findings showed that some of them needed specific guidance during the Learning Phase. Before the study, the participants were used to use an IDW as a board that they had to touch during activities in the communication and language unit (see this IDW in Figure 10). When they started the Learning Phase, some participants, instead of keeping the initial distance with the IDW, walked forward to touch it. In order words, they were behaving according to previous experiences using the same HW. This triggered the need for more trials for them to learn that the only way of playing Pictogram Room was by keeping the initial distance. Besides, some children tended to look for the stimuli in the real world so they easily left the game zone and the Kinect was unable to track them. Both these findings recall the difficulties that individuals with ASD have for processing the sense of agency (Russell, 1996) and forms of self-reflective awareness such as self-consciousness (Hobson, 1993). Considering this and knowing that this has been the first experience of these children using AR, it is not surprising that they needed support to learn and internalise the processes that are involved in seeing themselves as agents of action reflected on a screen who are able to interact with stimuli that are not available in the real world but in a virtual world (Herrera, Jordan, & Vera, 2006). Learning these processes could be decisive in the effectiveness of any AR-TMI (Herrera, Jordan, & Gimeno, 2006).

Based on all these findings, future studies may consider: (a) to use a different HW that does not necessarily trigger responses based on previous experiences (e.g., a white wall instead of an IDW); (b) to define the game zone using visual cues (e.g., applying colourful tape on the floor) as recommended in the literature (Mesibov et al., 2005); and (c) to include as many trials as needed during the Learning Phase to ensure that all participants can adequately use AR before they start the Intervention Phase. The latter recommendation would also contribute to the abovementioned need for giving the children with ASD enough time to succeed in new activities and building self-confidence. These two features could make the children feel more confident in using the AR system and might also have a direct impact on the effect of the intervention.

4.5 Generalization of the study outcomes

This study showed that this AR system does not appeal to all the individuals with ASD. Although P3's data was not finally included in this study for the reasons stated at the beginning of the results section, it is worth mentioning that he did not show any enthusiasm towards the technology in any of the sessions. It is unknown –because this goes beyond the aim of this study– if the lack of interest was due to the symptoms of ASD, ADHD, ID, a poor understanding of the AR functioning or that he simply does not like technology. In any case, this observation clearly supports previous studies which state that not all individuals with ASD feel attracted to –and benefit from– the use of technology (e.g., Brosnan & Gavin, 2015). It is worth mentioning that, as reported by Teacher A and Teacher B and observed by the researcher before the start of this study, P3's distracting behaviours were shown in all settings, during almost all of the activities and with all staff and family members so they could not be related to the study. Besides, it seems that ADHD symptoms could interfere with the performance of individuals when using AR. The results of the present study have shown that the other participant with ADHD diagnosis (i.e., P6) needed a relatively higher number of verbal and physical supports while playing games than the other five participants. Since it was observed that he engaged in games intermittently, it is suspected that his learning outcomes were not as successful as they could have been if he had maintained his attention span for longer. Future studies need to further explore this hypothesis.

Additionally, the findings have shown that this TMI can benefit children with higher cognitive abilities and milder ASD (i.e., P4) as well as children with lower cognitive abilities and more severe ASD (i.e., P2). By having the potential to benefit children of a wide range of cognitive levels and ASD severity, the current TMI study is more inclusive than many others that have been reviewed in Study 1 which only targeted individuals with higher cognitive abilities and milder forms of ASD (e.g., AS or HFA; Beaumont & Sofronoff, 2008; Golan & Baron-Cohen, 2006). This conclusion has been drawn based not only on the diagnostic information that was available in the archives of the communication and language unit but also from additional and updated information that was collected by the researcher (i.e., SCQ and Leiter-R). Future studies should consider the importance of confirming diagnoses that have been provided by external clinicians for drawing adequate conclusions about who could benefit from a given TMI.

It is a significant finding that five of the six participants mastered following the dummy's gaze and pointing to the right poster or turtle. Only P1 and P2 did not master to point to the right turtle. This result cannot be attributed to the possibility that the pupils were making choices instead of pointing to the turtle they thought was the target one, because this was controlled by means of the presentation of two turtles of the same colour in five of the ten trials on each session. Therefore, it is suspected that in case of having gone through a few more sessions, these two pupils would have mastered pointing to the right turtle as they mastered pointing to the right poster. Although P6 did not master pointing to the poster or to the turtle throughout the intervention, his improvements should be valued as significant, especially considering the interfering symptoms he might have as a result of his additional ADHD. More importantly, the fact that P6 did not master pointing to the right target should not be fully associated to his low cognitive level, since P2, who has an even lower cognitive level, correctly pointed to the right poster in all the trials of two sessions.

4.6 The present AR-TMI versus traditional intervention

One of the recommendations that are indicated in Study 1 and Study 2 is to compare, when this is possible, the use of technology with other traditional methods for evaluating the actual contribution of technology.

In an effort to include in the research design of this study a non-technological teaching condition, Teachers A and B were asked if they used a specific method for teaching JA in the communication and language unit. They reported the sporadic use of a reinforcement-based activity that resulted inefficacious, most probably due to the lack of pupils' engagement. For this reason, and acknowledging time constraints, all the priority was given to the use of the AR system and no comparison condition without technology was considered in this study.

However, if the traditional intervention is compared to the present TMI, it can be noted that both use teaching techniques based on reinforcement methods; pupils obtained a reward (i.e., a physical object in the traditional intervention, and a short video in the AR-TMI) after they gave a correct response in both interventions. Thus, the impact that the AR-TMI has had on the participants' engagement and improvements cannot be linked entirely to the teaching method (i.e., reinforcement) but to the AR as a medium for delivering the intervention as well.

4.7 Virtual world versus real world

One of the most remarkable findings of this intervention study is the generalisation that was observed when the pupils correctly followed the researcher's gaze and pointed to the target poster when this was placed behind them in the ESCS post-assessment, which is a response that was not practised in the virtual world during the intervention. Thus, although literature highlights the difficulties of people with ASD for transferring and generalising learnt skills (e.g., Ozonoff & Miller, 1995; Swettenham, 1996), this study demonstrated the ability of six children to follow the gaze of human eyes after having practised to follow the gaze of a virtual child. One factor that could explain this positive finding is related to the use of the dummy for assessing RJA after each intervention session. The dummy was similar to the virtual child in the sense that both had a non-expressive face that only moved the iris of the eyes. The dummy was also similar to the human in the sense that it was a real and tangible item. However, the three items were different in the sense that the participants needed to process much less information with the virtual child and the dummy than with the human's face, which often expresses complex information that is difficult to process at once for many individuals with ASD (Dawson, Webb, & McPartland, 2005). Although the dummy was used as an evaluating tool, it might have become to some extent a sort of facilitating tool for bridging the gap in between the virtual world and the real world. Future AR or VR technology intervention studies could explore this thought.

4.8 The importance of the setting and the interventionists

Two important factors, if not the most decisive ones, that have contributed to the success of this intervention study have been (a) the fact that it has been conducted in a school, and (b) the involvement of the school staff throughout the study. As it has been previously indicated in Study 1 and Study 2, and advised in Reichow et al.'s (2008) evaluative method, these factors are principal for the social validity of intervention studies with children with ASD. This study shows in many different ways why this is truly important.

To start, the school is a familiar setting where pupils go with a certain predisposition to learn. Moreover, teachers are highly motivated for contributing to pupils' learning outcomes. This may be specially the case of teachers like Teachers A and B, who were specialised in special educational needs and both had many years of experience teaching individuals with ASD. In the communication and language unit, Teachers A and B were the responsible of their pupils' learning and they knew, probably better than anybody else, about their pupils' curriculum and understood about their special needs, special abilities, sensory issues, communication system, interests and preferences. Their knowledge helped the researcher to (a) design the materials, (b) appropriately choose the rewards for each pupil, (c) include their PECS communication books as an essential item for the study sessions, (d) anticipate the study sessions in the pupils' PECS schedule boards, (e) consider the pupils' transitioning between the two settings (i.e., the communication and language unit and the audio-visual classroom), (f) prepare a digital timer, and (g) offer sensory-friendly sessions, as recommended by Bogdashina (2003). All these considerations have been crucial for the development of the study and many of them could have been missed if these teachers would not have been involved. Besides, this study has shown how school staff can be fully involved in the study and still be blind to some key points of the study (e.g., in which number session each pupil was at a given time), efficiently protecting the study from internal validity threats.

Considering all these aspects, future studies may consider the importance of conducting these types of interventions in natural environments such a school. It will also be principal to count with the participation of school staff who directly give support to the pupils with ASD and, preferably, has extensive expertise teaching pupils with ASD. Pupils' sensory issues should be acknowledged and considered. A bad experience (e.g., too loud music) with Pictogram Room or any other piece of technology could provoke, apart from unwished pain in the pupil, a rejection reaction towards the use of that piece of technology that would need to be extinguished later on, if that is ever possible. Last, but certainly not least, whenever possible, children's communicative system (e.g., PECS communication book) should be available for them to say, request or respond anytime.

5 Conclusion

In the present study, the effects of an AR-TMI to enhance JA skills were examined. The ultimate objective of this study was to improve the RJA skills of following another person's gaze and pointing to an object of shared attention in children with ASD through the use of Pictogram Room. A multiple baseline SSD was applied to seven participants; all of the six children who completed the assessment and intervention sessions improved performance in RJA after the intervention. Improvements were maintained over time and generalised to real-world situations. These findings demonstrate the potential of children with ASD for improving RJA skills when they are adequately taught with a targeted and engaging intervention.

Pictogram Room has been presented as a novel accessible and affordable easy-to-utilise technology that can be used with individuals with a wide range of special needs obtaining significant improvements in a relatively short period of time. This study has explored the impact of Pictogram Room on JA, but given the variety of games that the system offers, it could be used for enhancing other skills such as body scheme or imitation. Relevant implications for future research and practice have been addressed, being the selection of a natural setting and a familiar interventionist, the principal ones.

Finally, in an effort for designing and implementing the study with high rigour and strength levels, Reichow et al.'s (2008) evaluative method as well as the recommendations derived from the systematic reviews of Study 1 and Study 2 were significantly considered. As a result, this research allows for replication studies and is suitable for being included in possible future meta-analytic reviews, contributing to the promotion of EBP in the field.

Chapter 5

Final conclusions

1 Introduction

The principal aim of this thesis has consisted of reviewing the features and analysing the impact and quality of previous TMI studies and of a novel empirical study for individuals with ASD. The research work has been divided into three interconnected studies, each of which has had a specific aim. The objective of Study 1 has been to carry out a systematic review for describing the current research trends in TMI studies for individuals with ASD, including the analysis of eight features: (a) participant characteristics, (b) technology item(s) used, (c) target skill(s) addressed, (d) research design applied, (e) setting where the study was implemented, (f) country where the study was conducted, (g) year of publication, and (h) journal in which the TMI study was published. The objective of Study 2 has been twofold: (a) to carry out a systematic review for describing TMI studies which have focused on the improvement of JA skills in individuals with ASD, including in the analysis the same eight features as in Study 1, but also specifying which JA skills were addressed in the studies; (b) to determine the research quality and the level of evidence achieved in these studies. Study 3 aimed to explore the impact of an AR-TMI using Pictogram Room, which has been built on existent literature and rigorously conducted, on the RJA skills of gaze following and pointing in children with ASD. Each study has been presented in a different chapter (i.e., Study 1 in Chapter 2, Study 2 in Chapter 3, and Study 3 in Chapter 4) each of which included expanded discussion and conclusion sections.

In this chapter, a summary of the principal findings is presented by responding to the research questions that were formulated in the last section of Chapter 1 (p. 95). Furthermore, implications for research and practice derived from the findings of the three studies as a whole are summarized.

2 Principal findings

The findings of the three studies will now be summarised according to research questions.

2.1 Research question 1: which are the most prominent general trends in state-of-the-art of TMI research with individuals with ASD?

A total of 178 peer-reviewed papers which include 186 TMI studies published in English were identified through a systematic search conducted of four electronic databases (i.e., PsycINFO, ERIC, PubMed and WoS) for the years 2000-2015. The number of participants included in each study ranged from one –many studies had this *N*– to 121. Participants were mainly primary and secondary school age males. Females and adults were underrepresented in the studies. Some studies did not provide participants' gender and age information. Information on participant diagnosis did not allow for drawing clear conclusions given the heterogeneity of –or even the lack of information on– assessment tools and diagnostic labels used across the studies.

With regard to the ITs used, PCs followed by tablets, smartphone/small handheld devices and robots were the most extensively used HW. PCs were specially used with primary and secondary age participants. Tablets were mainly used with primary age participants. Smartphone/small handheld devices were specially used with secondary and post-secondary age participants. Robots were mainly used with early years or primary age participants and no robot was used with post-secondary age participants. All subcategories of HW were mainly used for enhancing social communication and social interaction skills except for smartphone/small handheld devices which were used more for enhancing life skills. PCs were highly used in studies conducted in schools and homes whereas smartphone/small handheld devices were highly used in vocational centres or work settings. The use of PC has remained relatively constant throughout the years whereas the use of tablets, although it started later, it has been gradually increasing in the last years. Generic SW was used more frequently than special needs SW or research SW. PCs were similarly used with the three subcategories of SW. Tablets were mostly used with special needs SW, smartphone/small handheld devices were predominantly used with generic SW, and robots were primarily used with research SW. Interactive sequence and prompting were clearly the most used methods for delivering TMIs. PCs were highly used for interactive sequences. Tablets were frequently used for delivering interactive sequences and sentence composition and speech generation. Smartphone/small handheld devices were mainly used for prompting. Robots were largely used for presenting interactive agents. All subcategories of MoD were mainly used for enhancing social communication and social interaction skills except for interactive sequence, which was used more for enhancing academic skills, and prompting, which was mainly used for enhancing life skills. Prompting was the preferred method for delivering interventions in vocational or work settings.

TMI studies overall focused on social communication and social interaction skills. Studies aimed at early years and primary age children mainly focused on social communication and social interaction, studies aimed at secondary age participants mostly focused on academic skills, and studies aimed at post-secondary individuals principally focused on life skills. Most studies applied SSDs, especially multiple baseline and multiple probe designs. Regarding group designs, the number of studies that included control group was equal to the number of studies that did not include control group. The number of studies that applied RCTs was minimal and most RCTs were applied in the last three years. Generally, studies with somewhat larger numbers of participants (i.e., $N > 10$) applied group designs, whereas studies with a smaller number of participants (i.e., $N < 10$) mostly applied SSDs.

Most of the TMI studies were conducted in real-world settings, especially in schools. The vast majority of the studies that aimed at primary and secondary age participants were conducted in schools, whereas all the studies conducted in vocational centres or work environments aimed at post-secondary age participants. Academic skills were principally targeted in schools. Most of home-based studies focused on social communication and social interaction studies whereas none focused on life skills. Most studies conducted in day centres, vocational centres or work settings mainly focused on life skills. Some studies did not provide information on the setting. The studies took place in 22 different countries. The US has been the country in which more TMI studies were conducted, followed by the UK. Some publications did not indicate the country in which the study was conducted.

The number of publications on TMI studies has been gradually increasing since 2010. The number of publications on TMI studies for 2010-2015 increased by 214% compared to 2000-2009, and the number of publications published in 2015 increased by 38% compared to the previous year. The 178 papers have been published in 75 different journals, 45 of which are included in the JCR (Thomson Reuters, 2016). A large number of TMI studies have been published in ASD and special needs journals, especially in the *Journal of Autism and Developmental Disorders*, *Research in Autism Spectrum Disorders* and *Focus on Autism and Other Developmental Disabilities*.

2.2 Research question 2: which are the most prominent trends in state-of-the-art of TMI research with individuals with ASD with regard to JA skills?

Five TMI studies published in English in peer-reviewed journals which focused on the enhancement of JA in individuals with ASD were identified through a systematic search conducted of four electronic databases (i.e., PsycINFO, ERIC, PubMed and WoS) for the years 2000-2015. A total of 23 males with different diagnoses (i.e., ASD, moderate and severe autism, PDD and autism) between 2 and 12 years of age participated in the studies. With regard to the ITs, four studies used robots (i.e., Nao, Troy and KASPAR) and one study VR technology (i.e., JASL). All of the studies used research SW. The robots were used to deliver interactive agents whereas the VR was used for both delivering interactive agents as well as simulation environments. No studies compared the effect of the selected IT to another type of IT and only one study compared the effect of the TMI to another traditional method that did not include ITs. One of the studies used the TMI as part of a wider therapy framework which was based on a variety of behavioural techniques. The studies focused on a wide range of IJA and RJA. The most targeted IJA skills across the studies were looking and pointing spontaneously to direct the partner's gaze towards an object or event of interest. The most targeted RJA skills were following eye gaze, turning the head and pointing in response to a partner's action or request. Three studies applied SSDs (i.e., AB, ABAC and multiple probe) and two studies applied group designs without control or comparison group. Three studies were conducted in laboratories located in universities or research centres. One study was conducted in a clinic and another study in a primary school for children with special needs. Two studies were conducted in the US, one in the UK, one in Romania and one in Taiwan. Three studies were published in 2012 and two papers in 2015. Two papers were published in ASD and special needs journal, another two papers were published in computer science and technology journals, and one paper was published in a journal that has an interdisciplinary focus on computer science and technology, psychology, education and medicine.

2.3 Research question 3: to what degree can existing TMI research on JA skills in the field of ASD be considered EBP?

All of the five studies reviewed rated weak, mainly due to a lack of participant characteristics description, an absence of generalisation and maintenance assessment and the participation of interventionists who were unfamiliar to the children with ASD. The two group design studies neither included control or comparison group nor indicated the effect size of the TMIs. Only one of the three SSD studies informed of baseline condition, visual analysis and experimental control. Due to the numerous unsuccessful rigour ratings obtained by each study, none of them received strong or even adequate strength ratings. Consequently, although the TMIs were effective for 21 of the 23 participants involved, these cannot be considered EBP.

2.4 Research question 4: to what extent can the use of a novel IT be effective in improving JA skills in children with ASD?

A novel AR-TMI using Pictogram Room has been found to be effective to enhance the RJA skills of gaze following and pointing to an object of shared attention in six early years and primary age children with ASD. Their RJA abilities increased after six intervention sessions and the improvements were maintained over time and generalised to real-world situations.

2.5 Research question 5: to what extent can a real-world TMI contribute to the promotion of EBP in the ASD field?

Using Reichow et al.'s (2008) evaluative method as well as the recommendations derived from Study 1 and Study 2, this novel TMI has obtained a high rigour and strength levels, which makes it eligible for replication studies and future meta-analytic reviews and contributes to the establishment of EBP in the field.

3 Principal implications for research and practice

A number of implications for research and practice can be drawn when reflecting on the three studies of this thesis.

3.1 Implications for research

Some good research practices have been identified in this thesis and should continue in the future. Due to the continuous growth in the number of TMI studies, it becomes necessary to keep doing all types of reviews: narrative and systematic. In different ways both contribute to integrate, synthesise and build conclusions on an existent bunch of research studies. When these studies allow for quantitatively evaluating the TMIs effectiveness, systematic reviews should include meta-analyses. As a novelty, given the high number of existent reviews in the field, it would be interesting to carry out an overview of reviews. Considering the importance of life skills for the wellbeing, independence and inclusion of individuals with ASD, future research should keep focusing on the enhancement of these skills. Studies focusing on life skills and studies focusing on social and academic skills should be considered equally important, because adults with ASD could function more independently and children with ASD could be better prepared for the transition into adulthood. Moreover, it is desired the use of robots, VR and AR for the enhancement of JA skills since previous TMI studies have indicated to be effective. Given the heterogeneity among individuals with ASD, it is desirable that methodologically strong SSDs are considered appropriate to evaluate the effectiveness of TMIs. It is recommended to keep applying sophisticated SSDs such as multiple baseline or multiple probe designs when the number of participants is small and keep applying group designs with control or comparison group –preferably with randomization– when the number of participants is larger. Given the potential that rigorous RCTs have for establishing causal relations between a TMI and the outcomes, the trend of conducting more and more RCTs should continue as long as the number of participants included allow for it. For strengthening the social validity of the study, TMIs should be conducted in real-world settings such as home or school where the person with ASD naturally performs the skills that are being enhanced through the use of ITs. It would be of particular benefit if research studies, which include individuals with ASD, continue being published in journals that specialise in ASD, or at least in special educational needs, so that experts in the field are more likely to have checked the research gaps these studies attempt to fill, their accuracy and rigour, and their ethical procedures.

Several limitations have also been identified in this thesis and should be avoided in future. Research studies should include in the title or the abstract of the publication the keywords of the work –including the specific skills the TMI targets– for facilitating other researchers to locate the study through a systematic search. Due to their demonstrated importance, future empirical studies should also provide information on the features analysed in this thesis, especially providing a full description of participant characteristics (i.e., number, gender, age and diagnosis). Further, additional information on cognitive and language abilities as well as the occurrence of comorbidities (e.g., ID, ADHD) should be provided. When possible, the assessment tools and diagnostic criteria used should be indicated. Providing all this information can enable researchers to draw conclusions and generalise the results more accurately as well as to replicate the study. Interventionists' characteristics should also be fully described in future studies to adequately analyse the social validity of the TMI. Including interventionists who are familiar to the individuals with ASD will contribute to the success of the TMI as well as to its maintenance and generalization. Considering the ratio of males and females with ASD and the findings, more females should be included in future empirical studies. Because adults can also benefit from TMI studies, a higher number of post-secondary participants should be included in future empirical studies. To evaluate the actual impact of the chosen IT, future research should compare the use of a given IT and that of traditional methods or other pieces of IT. Exploring the effectiveness of robot-based TMI studies on older participants with ASD could inform future research. Considering ITs access and affordance, the research community may want to look at ways for developing inexpensive robots as well as SW for robots for the general public or for people with special needs that end up being commercialized. Doing so would facilitate its use by other interested users. Given the need for more work inclusion of individuals with ASD and the increasing presence of tablets in work environments, more research studies focusing on the use of tablets in work settings would be beneficial. It would be recommended to do more research focusing on life skills in homes, where individuals with ASD can benefit from the practicality of the TMIs. Future review studies may want to use the classification systems that have been provided for ITs in this thesis (i.e., HW, SW and MoD) as well as for target skills to provide a thorough list of ITs and skills and to bring closer and closer a consensus on ITs and skills classifications.

Studies that apply group designs should include a comparison or control group and randomly allocate participants to the groups (i.e., RCT). The inclusion of a larger number of participants should be considered and the implementation of an intervention to a single participant should be avoided, unless it is exceptionally necessary. Finding a unique IT solution for all the individuals with ASD might be unreachable, but always looking for one specific solution for each individual with ASD is not a good approach either. The optimal is to design IT solutions which are suitable for as many individuals with ASD as possible in a way that big efforts invested in developing TMIs can benefit the maximum number of individuals. Given the requirements for a study to be included in a meta-analytic review and for knowing about the effectiveness of a TMI, it is fundamental to provide an effect size –or at least the data that is needed for calculating them (e.g., number of participants, arithmetic mean and standard deviation)– in future studies. It is important to include the evaluation of the generalisation and maintenance of the targeted skills. More studies across settings are needed for evaluating the generalisability of the acquired skills to other settings. Using Reichow et al.'s (2008) evaluative method, or any other available method for analysing the quality of research reports, can help to design and rigorously conduct future empirical studies and evaluate the quality of a set of primary studies in future reviews. More replication studies need to be conducted since by doing so, regardless of the research field, is the best way to establish EBP and, more generally, to advance in science.

3.2 Implications for practice

Since EBP informs of consistent effectiveness, clinicians, practitioners and carers should be highly encouraged to use available online catalogues for finding and using ITs which have been established as EBP. However, they need to be cautious because the information of these resources is not always reliable and needs so to be evaluated in the light of other evidence available. The success of a TMI highly depends on its personalisation. Given that carers and professionals are the ones who tend to provide most information on the person with ASD (e.g., communication system, sensory issues, interests and preferences), it is essential that they find ways for working cooperatively with researchers for the development and implementation of TMI studies. It is recommended that TMIs are relatively short, easy to implement and based on accessible and affordable ITs so that clinicians, practitioners and carers can deliver the TMIs themselves in real-world settings such as therapy centres, schools and homes. By doing so, individuals with ASD will benefit from ecologically-valid practices. ITs can be used separated from the typical individuals' routines but they can also be used within more comprehensive interventions that use other traditional teaching techniques. The second option may help to include the use of ITs in the busy agendas of many individuals with ASD. Clinicians, practitioners and carers should consider teaching the person with ASD to adequately use the IT before starting any TMI. Tools such as timers can be used to indicate that the time for using the IT is over to avoid undesired circumstances such as high dependence on ITs and tantrums. Due to the importance of JA skills for infant development, these skills should be the focus of many interventions at therapy centres, schools and homes. Different TMI studies have been shown to be effective, especially an AR-TMI study which uses accessible and affordable HW and SW (i.e., Pictogram Room). Given that learning outcomes highly depend on the engagement of the individuals with ASD, choosing ITs and customise them according to individuals' preferences and interests will increase the likelihood of a TMI being effective. Considering that not all individuals with ASD feel affinity for ITs, clinicians, practitioners and carers can be in the situation of wanting to use a specific IT which has been effective with other people but it does not attract the person with ASD they want to use it with.

The researcher would like to close this section on implications for practice with presenting a list of principles that Fleming, Hurley, and the Goth (2015) described in their book in order to support parents and practitioners to select the right ASD interventions based on research evidence. Although these principles are not specifically developed for TMIs, they are applicable with any type of interventions. According to the authors, a good intervention should:

1. be based on good understanding of ASD (e.g., ASD is a neurodevelopmental disorder, not an illness)
2. be adapted to the needs of the person with ASD (e.g., communication system, sensory issues)
3. be based on a scientific theory (i.e., one of the principles for EBP)
4. be evidence-based (although this does not imply that the intervention will be effective for all individuals with ASD)
5. work in real-world settings (e.g., school and home)
6. consist of a set of instructions, which are clearly described so they allow for replication
7. be continuously reviewed and, therefore, updated with the newest findings
8. provide significant outcomes
9. not cause any important physical or emotional injury
10. specify benefits which minimise any costs
11. be good value for time and money
12. be delivered by an interventionist who:
    - knows the person with ASD well and respect his/her wishes
    - is a qualified and experienced professional
    - seeks the person’s consent and willingness to participate throughout the intervention

4 Final consideration

Bearing in mind the fast development of ITs and their short lifecycle, the researcher wonders: “For how long this thesis will be informative?” Most probably ITs which do not appear in this work have been used with individuals with ASD during the time this was being written and some of the ITs that do appear in this work have evolved or they do not even longer exist. In this sense, this thesis may become obsolete relatively soon. Gratefully, this thesis does not only inform the reader on the use of specific ITs but also highly contributes to the ASD field by providing methods and ways forward to advance in research and practice that will be useful for much longer. This thesis can be especially helpful to researchers, clinicians, practitioners and carers who often use ITs with individuals with ASD or want to use them for the first time. They are, after all, the ones who may want to rigorously evaluate the actual contribution of the use of ITs to better know if what they are doing is good and beneficial for the person with ASD.

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Appendices

Appendix A

Formulas used in the databases for the search of papers

((((ti(Autis*)) OR (ti(ASD)) OR (ti(ASC)) OR (ti(Asperger Syndrome)) OR (ti(Pervasive Developmental Disorder)) OR (ti(PDD*))) AND ((ti(Technolog*)) OR (ti(TEL)) OR (ti(Computer*)) OR (ti(CAT)) OR (ti(Virtual*)) OR (ti(Robot*)))) OR (((ab(Autis*)) OR (ab(ASD)) OR (ab(ASC)) OR (ab(Asperger Syndrome)) OR (ab(Pervasive Developmental Disorder)) OR (ab(PDD*))) AND ((ab(Technolog*)) OR (ab(TEL)) OR (ab(Computer*)) OR (ab(CAT)) OR (ab(Virtual*)) OR (ab(Robot*)))))

Figure A1. Formula used in PsycINFO and ERIC databases.

(((Autis*[Title/Abstract]) OR (ASD[Title/Abstract]) OR (ASC[Title/Abstract]) OR (Asperger Syndrome[Title/Abstract]) OR (Pervasive Developmental Disorder[Title/Abstract]) OR (PDD*[Title/Abstract])) AND ((Technolog*[Title/Abstract]) OR (TEL[Title/Abstract]) OR (Computer*[Title/Abstract]) OR (CAT[Title/Abstract]) OR (Virtual*[Title/Abstract]) OR (Robot*[Title/Abstract])))

Figure A2. Formula used in PubMed database.

TS=((Autis* OR ASD OR ASC OR "Asperger Syndrome" OR "Pervasive Developmental Disorder" OR PDD*) AND (Technolog* OR TEL OR Computer* OR CAT OR Virtual* OR Robot*))

Figure A3. Formula used in WoS database.

Appendix B

Table B1. Information extracted from the reviewed studies.

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
1	Achmadi et al. (2012)	Research in Autism Spectrum Disorders	2 males	13-17	ASD	Small handheld	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Multiple probe	School	New Zealand
2	Alexander et al. (2013)	Research in Autism Spectrum Disorders		15-18	Moderate autism	Tablet	Generic	Prompting	Life			School	US
	Study 1		2 males 1 female							SSD	Multiple probe		
	Study 2		4 males							SSD	Multiple probe		
3	Allen et al. (2015)	Behavior Modification	1 female	17	ASD	Tablet	Special needs	Prompting	Life	SSD	Multiple baseline	Home, community	US
4	Armstrong & Hughes (2012)	International Journal of Special Education	5 males	7-8	HFA	PC	Generic	Interactive sequence	Academic	SSD	Alternating treatment	School	US
5	Arthanat et al. (2013)	Assistive Technology	3 males	12-13	ASD, autism	PC, tablet	Generic	Interactive sequence	Academic	SSD	Multiple baseline	School	US
6	Ayres et al. (2009)	Education and Training in Autism and Developmental Disabilities	2 males 1 female	7-9	Autism	PC	Research	Prompting, simulation	Life	SSD	Multiple probe	School, home	US
7	Barakova et al. (2015)	Expert Systems	6 males	8-12	Autism, PDD-NOS	Robot	Research	Interactive agent	Social communication, interaction	SSD	Multiple baseline	Therapy centre	Netherlands

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
8	Bauminger-Zviely et al. (2013)	Autism: The International Journal of Research and Practice	18 males 4 females	N/A	HFA	PC	Special needs	Collaborative games	Social communication, interaction	GD	With control group, not randomised	School	Israel
9	Beaumont & Sofronof (2008)	Journal of Child Psychology and Psychiatry	44 males, 5 females	7-11	AS	PC	Special needs	Simulation	Social communication, interaction	GD	With control group, experiment	University	Australia
10	Beaumont et al. (2015)	Psychology in the Schools	64 males, 5 females	7-12	HFA, AS, PDD-NOS	PC	Special needs	Simulation	Social communication, interaction	GD	Without control group	School	Australia
11	Bereznak et al. (2012)	Journal of Development and Physical Disabilities	3 males	15-18	ASD	Small handheld	Generic	Prompting	Life	SSD	Multiple probe	School	UD
12	Bernardini et al. (2014)	Information Sciences	18 males, 1 female	4-14	ASD, AS	PC	Research	Interactive agent	Social communication, interaction	GD	Without control group	School	UK
13	Bernard-Opitz et al. (2001)	Journal of Autism and Developmental Disorders	6 males, 2 females	5-8	Autism	PC	Research	Interactive sequence	Social communication, interaction	SSD	Multiple probe	N/A	Singapore
14	Bhattacharya et al. (2015)	International Conference on Interaction Design and Children	13 males 5 females	8-19	Autism	PC	Research	Simulation	Social communication, interaction, life	GD	Without control group	School	US

(*continued*)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
15	Bolte et al. (2002)	International Journal of Circumpolar Health	10 males	16-40	HFA, AS	PC	Research	Interactive sequence	Social communication, interaction	GD	With control group, not randomised	N/A	Germany
16	Bosseler & Massaro (2003)	Journal of Autism and Developmental Disorders		7-12	Autism	PC	Research	Interactive agent	Academic			School	US
	Study 1		7 males 1 female							SSD	AB		
	Study 2		5 males 1 female							SSD	Multiple baseline		
17	Bouck et al. (2014)	Journal of Autism and Developmental Disorders	3 males	6-10	ASD	PC	Generic	Interactive sequence	Academic	SSD	Alternating treatment	Therapy centre	US
18	Boyd et al. (2015)	ACM Transactions on Accessible Computing	7 males 1 female	8-11	ASD	Tablet	Generic	Collaborative games	Social communication, interaction	SSD	Reversal	School	US
19	Burckley et al. (2015)	Developmental Neurorehabilitation	1 female	18	PDD-NOS	Tablet	Generic	Prompting	Life	SSD	Multiple probe	Community	US
20	Burke et al. (2013)	Journal of Vocational Rehabilitation	4 males	19-28	Autism, AS	Tablet	Special needs	Prompting	Life	SSD	Multiple baseline	Home, work	US

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
21	Burke et al. (2010)	Research in Developmental Disabilities		18-27	Autism, AS, PDD-NOS	Small handheld	Research	Prompting	Social communication, interaction, life			Work	US
	Study 1		3 males							SSD	Alternating treatment		
	Study 2		3 males							SSD	Alternating treatment		
22	Campbell et al. (2015)	OTJR: Occupation, Participation, and Health	2 males 1 female	17-19	Autism, PDD	Small handheld	Generic	Prompting	Life	SSD	Multiple baseline	School	US
23	Campillo et al. (2014)	Autism: The International Journal of Research and Practice	2 males 1 female	19-29	ASD	Tablet	Special needs	Augmented information	Life	SSD	AB	Day centre	Spain
24	Cannella-Malone et al. (2006)	Education and Training in Autism and Developmental Disabilities	5 males 1 female	27-41	Autism, AS, PDD	PC	Generic	Prompting	Life	SSD	Multiple probe, alternating treatment	Work	US
25	Carlile et al. (2013)	Education & Treatment of Children	4 males	8-12	Autism	Small handheld	Generic	Interactive sequence	Life	SSD	Multiple probe	School	US
26	Chabani & Hommel (2014)	Journal of Autism and Developmental Disorders	42 males 6 females	N/A	ASD	PC	Research	Interactive sequence	Academic	GD	With control group, not randomised	School	Netherlands

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
27	Chen & Lin (2015)	Research in Developmental Disabilities	2 males 1 female	10-13	ASD	PC	Research	Simulation	Social communication, interaction	SSD	Multiple baseline	School	Taiwan
28	Cheng & Huang (2012)	Research in Developmental Disabilities	3 males	9-12	PDD	PC	Research	Interactive agent, simulation	Social communication, interaction	SSD	Multiple probe	Laboratory	Taiwan
29	Cheng et al. (2010)	Computers & Education	3 males	8-10	ASC	PC	Research	Simulation	Social communication, interaction	SSD	Multiple probe	School	Taiwan
30	Cheng et al. (2015)	Focus on Autism and Other Developmental Disabilities	3 males	10-12	ASD	PC	Research	Simulation	Social communication, interaction	SSD	Multiple probe	School	Taiwan
31	Cheng & Ye (2010)	Computers & Education	2 males 1 female	7-8	ASC	PC	Research	Interactive agent, simulation	Social communication, interaction	SSD	Multiple probe	School	Taiwan
32	Cihak et al. (2010)	Journal of Positive Behavior Interventions	3 males 1 female	6-8	Severe autism	Small handheld	Generic	Prompting	Life	SSD	Reversal	School	US
33	Cihak et al. (2010)	Education and Training in Autism and Developmental Disabilities	3 males	11-13	HFA	Small handheld	Generic	Prompting	Academic, life	SSD	Multiple probe, reversal	School	US
34	Coleman et al. (2015)	Intellectual and Developmental Disabilities	1 male 1 female	10-11	Autism	PC	Generic	Interactive sequence	Academic	SSD	Alternating treatment	School	US

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
35	Coleman-Martin (2005)	Focus on Autism and other Developmental Disabilities	1 female	12	Autism	PC	Generic	Interactive sequence	Academic	SSD	Alternating treatment	School	US
36	Costa et al. (2015)	International Journal of Social Robotics	8 males	6-9	Autism	Robot	Research	Interactive agent	Social communication, interaction, academic	GD	Without control group	School	UK
37	Costa et al. (2010)	Annual International Conference of the IEEE Engineering in Medicine and Biology Society	2 males	N/A	Autism	Robot	Research	Interactive agent	Social communication, interaction, life	SSD	Exploratory	Therapy centre	Portugal
38	Crutchfield et al. (2015)	Journal of Autism and Developmental Disorders	2 males	14	Autism	Small handheld	Special needs	Prompting	Life	SSD	Multiple baseline reversal	School	US
39	Dauphin et al. (2004)	Journal of Positive Behavior Interventions	1 male	3	ASD	PC	Generic	Prompting, augmented information	Social communication, interaction	SSD	Multiple baseline	Home	US
40	De Vries et al. (2015)	Journal of Child Psychology and Psychiatry	121 N/A	8-12	ASD	PC	Special needs	Interactive sequence	Academic	GD	With control group, randomised	University	Netherlands
41	Desai et al. (2014)	Computers & Education	1 male	13	ASD	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	AB	School	Canada

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
42	De Thorne et al. (2015)	Journal of Autism and Developmental Disorder	6 N/A	3-8	Autism	PC	Special needs	Interactive sequence	Social communication, interaction	GD	With control group, not randomised	Therapy centre	US
43	Dickinson & Place (2014)	Autism Research and Treatment	79 males 21 females	5-15	Autism	Video console	Generic	Simulation	Life	GD	With control group, randomised	School	UK
44	Duquette et al. (2008)	Autonomous Robotics	4 N/A	4-5	LFA	Robot	Research	Interactive agent	Social communication, interaction	SSD	Reversal	School	Canada
45	Edrisinha et al. (2011)	Research in Developmental Disabilities	4 males	33-41	Autistic Disorder, PDD	PC	Generic	Prompting	Life	SSD	Multiple probe	Residential care facility	US
46	Faja et al. (2008)	Developmental Neuropsychology	10 males	12-32	HFA	PC	Generic	Interactive sequence	Social communication, interaction	GD	With control group, not randomised	N/A	US
47	Faja et al. (2012)	Journal of Autism and Developmental Disorders	13 N/A	N/A	HFA	PC	Generic	Interactive sequence	Social communication, interaction	GD	Without control group	University	US
48	Ferguson et al. (2013)	Child & Family Behavior Therapy	6 males	7-11	Autism, AS, PDD-NOS	Video console	Generic	Simulation	Social communication, interaction	SSD	Multiple baseline	Therapy centre	US
49	Fernandes et al. (2010)	Pro-Fono: Revista de Atualização Scientifica	23 N/A	3-12	ASD	PC	Generic	Interactive sequence	Social communication, interaction	GD	Without control group	Therapy centre	Brasil

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
50	Flores et al. (2012)	Augmentative and Alternative Communication	3 males	8-9	ASD	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Multiple probe	University	US
51	Flores et al. (2014)	Journal of Special Education Technology	4 males 1 female	3-8	ASD	Tablet	Generic	Prompting	Social communication, interaction, life	SSD	AB	School	US
52	Ganz et al. (2015)	Developmental Neurorehabilitation	1 male	4	Autism	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction, academic	SSD	Multiple baseline	Therapy centre	US
53	Ganz et al. (2014)	Focus on Autism and other Developmental Disabilities	2 males 1 female	8-14	ASD	Tablet	Special needs	Augmented information	Academic	SSD	Alternating treatment	School, home	US
54	Gentry et al. (2015)	Journal of Autism and Developmental Disorders	42 males 8 females	18-60	ASD	Small handheld	Generic	Prompting, interactive sequence	Life	GD	With control group, randomised	Work	US
55	Golen & Baron-Cohen (2006)	Development and Psychopathology		17-52	HFA, AS	PC	Special needs	Interactive sequence	Social communication, interaction			Home	UK
	Study 1		31 males 10 females							GD	With control group, not randomised		
	Study 2		20 males 4 females							GD	With control group, not randomised		

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
56	Goodrich et al. (2012)	IEEE Intelligent Systems	2 males	3-8	ASD	Robot	Research	Interactive agent	Social communication, interaction	SSD	AB	N/A	US
57	Grosberg & Charlop (2014)	Journal of Developmental and Physical Disabilities	3 males 1 female	8-9	Autism	Small handheld	Generic	Prompting	Social communication, interaction	SSD	Multiple baseline	School	US
58	Grossman et al. (2013)	Journal of Autism and Developmental Disorders	34 males 5 females	7-13	HFA, AS, PDD-NOS	PC	Generic	Interactive sequence	Social communication, interaction	GD	With control group, randomised	Laboratory	Canada
59	Herrera et al. (2008)	Autism: The International Journal of Research and Practice	2 males	8-15	Autism	PC	Research	Simulation	Social communication, interaction, life	SSD	AB	Therapy centre	Spain
60	Hetzroni & Shalem (2005)	Focus on Autism and other Developmental Disabilities	3 males 3 females	10-13	Autism	PC	Research	Simulation	Academic	SSD	Multiple probe	School	Israel
61	Hetzroni & Tannous (2004)	Journal of Autism and Developmental Disorders	3 males 2 females	7-12	Autism	PC	Research	Interactive sequence	Social communication, interaction	SSD	Multiple baseline	School	Israel
62	Hill & Flores (2014)	Tectrends	2 males 1 female	3-9	ASD	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Alternating treatment	School	US

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
63	Hill et al. (2013)	Journal of Applied Rehabilitation Counseling	1 male 2 females	23-26	ASD	Tablet	Generic	Prompting, interactive sequence	Life	SSD	Exploratory	University, work	US
64	Hopkins et al. (2011)	Journal of Autism and Developmental Disorders	44 males 5 females	6-15	HFA, LFA	PC	Special needs	Interactive agent	Social communication, interaction	GD	With control group, randomised	School	US
65	Humm et al. (2014)	Annual Review of CyberTherapy and Telemedicine	20 males 6 females	N/A	ASD	PC	Special needs	Interactive agent	Life	GD	With control group, randomised	N/A	US
66	Huskens et al. (2015)	Journal of Autism and Developmental Disorders	3 males	5-10	ASD, AS	Robot	Research	Interactive agent	Social communication, interaction	SSD	Multiple baseline	Therapy centre	Netherlands
67	Huskens et al. (2013)	Developmental Neurorehabilitation	6 males	8-12	Autism, ASD, PDD-NOS	Robot	Research	Interactive agent	Social communication, interaction	SSD	Multiple baseline, alternating treatment	School, day centre	Netherlands
68	Isong et al. (2014)	Clinical Pediatrics	65 males 15 females	7-17	ASD	Conventional player	None	Prompting	Life	GD	With control group, randomised	Therapy centre	US
69	Josman et al. (2008)	International Journal on Disability and Human Development	5 males 1 female	8-16	Autism, PDD	PC	Research	Simulation	Life	GD	Without control group	School	Israel

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
70	Kagohara et al. (2012)	Research in Autism Spectrum Disorders		13-17	ASD	Tablet, small handheld	Special needs	Sentence composition, speech generation	Academic			School	New Zealand
	Study 1		2 males							SSD	Multiple probe		
	Study 2		2 males							SSD	Multiple probe		
71	Kagohara et al. (2010)	Clinical Case Studies	1 male	17	Autism	Small handheld	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Reversal	School	New Zealand
72	Kandalaft et al. (2013)	Journal of Autism and Developmental Disorders	6 males 2 females	18-26	HFA	PC	Generic	Simulation	Social communication, interaction	GD	Without control group	University	US
73	Ke & Im (2013)	The Journal of Educational Research	2 males 2 females	9-10	HFA, AS	PC	Generic	Interactive agent, simulation	Social communication, interaction	SSD	Multiple baseline	Home, school, parents' offices	US
74	Kilroi et al. (2014)	Behavioral Development Bulletin	3 males 1 female	8-10	Autism	PC	Generic	Interactive sequence	Academic	SSD	Multiple baseline	School	Ireland
75	Kinney et al. (2003)	Journal of Positive Behavior Interventions	1 female	8	ASD	PC	Generic	Prompting interactive sequence	Academic	SSD	Exploratory	School, home	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
76	Knight et al. (2015)	Focus on Autism and other Developmental Disabilities	3 males 1 female	11-14	ASD	PC	Special needs	Interactive sequence	Academic	SSD	Multiple probe, alternating treatment	School	US
77	Kozina et al. (2007)	Progress in Brain Research	1 male 2 females	3-4	Autism, AS	Robot	Research	Interactive agent	Social communication, interaction	SSD	Exploratory	Day centre	Japan
78	LaCava et al. (2007)	Remedial and Special Education	6 males 2 females	8-11	AS	PC	Special needs	Interactive sequence	Social communication, interaction	GD	Without control group	School, home	US
79	LaCava et al. (2010)	Autism: The International Journal of Research and Practice	4 males	7-9	Autism, PDD-NOS	PC	Special needs	Interactive sequence	Social communication, interaction	SSD	Multiple baseline	School	US
80	LeBlanc et al. (2003)	Journal of Applied Behavior Analysis	3 males	7-13	Autism	Conventional player	None	Prompting	Social communication, interaction	SSD	Multiple baseline	School, after-school centre	US
81	Leytham et al. (2015)	Research in Autism Spectrum Disorders	1 male 1 female	12-13	ASD	PC	Generic	Interactive sequence	Academic	SSD	Multiple probe, alternating treatment	School	US
82	Lindsey-Glenn & Gentry (2008)	Teaching Exceptional Children	1 male	11	ASD	PC, small handheld	Generic	Prompting, interactive sequence	Academic	SSD	Exploratory	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
83	Lorah & Karnes (2015)	Journal of Developmental and Physical Disabilities	1 male 1 female	3-4	Autism	Tablet	Special needs	Interactive sequence	Social communication, interaction, academic	SSD	Multiple baseline	Therapy centre	US
84	Lorah et al. (2015)	Journal of Developmental and Physical Disabilities	1 male 1 female	8-12	Autism	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Multiple baseline	Therapy centre	US
85	Lorenzo et al. (2013)	Computers & Education	16 males 4 females	8-15	AS	PC	Research	Simulation	Social communication, interaction, academic	GD	Without control group	University	Spain
86	Macpherson et al. (2015)	Journal of Autism and Developmental Disorders	4 males 1 female	9-11	ASD	Tablet	Generic	Prompting	Social communication, interaction	SSD	Multiple baseline	Therapy centre	US
87	Maione & Mirenda (2006)	Journal of Positive Behavior Interventions	1 male	5	Autism	Conventional player	None	Prompting	Social communication, interaction	SSD	Multiple baseline	Home	Canada
88	Mancil et al. (2009)	Focus on Autism and other Developmental Disabilities	2 males 1 female	6-9	Autism	PC	Generic	Interactive sequence	Life	SSD	Alternating treatment	School	US
89	Maskei et al. (2014)	PloS One	9 males	7-13	ASD	PC	Generic	Simulation	Life	SSD	AB	N/A	UK
90	Massaro & Bosseler (2006)	Autism: The International Journal of Research and Practice	4 males 1 female	8-13	Autism	PC	Research	Interactive agent	Academic	SSD	Alternating treatment	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
91	Matsuda & Yamamoto (2014)	Research in Autism Spectrum Disorders	2 males	4-8	Autistic Disorder, PDD-NOS	PC	Generic	Interactive sequence	Social communication, interaction	SSD	Multiple baseline	University	Japan
92	McEwen (2014)	Information, Communication, & Society	9 males 3 females	N/A	ASD	Small handheld	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	AB	School	Canada
93	McKissik et al. (2013)	Research in Autism Spectrum Disorders	2 males 1 female	9-10	Autism	PC	Generic	Interactive sequence	Academic	SSD	Multiple probe	School	US
94	Mechling et al. (2015)	Focus on Autism and other Developmental Disabilities	4 males	15-19	ASD	PC	Generic	Prompting	Life	SSD	Alternating treatment	School	US
95	Mechling et al. (2006)	Focus on Autism and other Developmental Disabilities	2 males	13-14	Mild autism, moderate autism	Conventional player	None	Prompting	Academic	SSD	Reversal	School	US
96	Mechling et al. (2009)	Journal of Autism and Developmental Disorders	3 males	16-17	Mild autism, moderate autism	Small handheld	Generic	Prompting	Life	SSD	Multiple probe	School	US
97	Mechling & Savidge (2011)	Journal of Autism and Developmental Disorders	2 males 1 female	14	Moderate autism	Small handheld	Generic	Prompting	Academic	SSD	Multiple probe	School	US
98	Mechling & Swindle (2013)	The Journal of Special Education	3 males	7-11	Autism, PDD-NOS	PC	Generic	Prompting	Life	SSD	Multiple probe	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
99	Miltenberger & Charlop (2015)	Journal of Developmental and Physical Disabilities	4 males 1 female	5-12	ASD	PC, tablet	Generic	Prompting	Social communication, interaction	SSD	Multiple baseline, alternating treatment	Therapy centre, community	US
100	Mitchell et al. (2007)	Journal of Autism and Developmental Disorders	3 males 3 females	14-15	Autism, AS, ASD	PC	Generic	Simulation	Social communication, interaction	SSD	Reversal	School	UK
101	Moore & Calvert (2000)	Journal of Autism and Developmental Disorders	12 males 2 females	3-6	Autism	PC	Research	Interactive sequence	Academic	GD	Without control group	School	US
102	Murdock et al. (2013)	Journal of Autism and Developmental Disorders	4 males	4	Autism, PDD-NOS	Tablet	Generic	Interactive sequence	Social communication, interaction	SSD	Multiple baseline	Therapy centre	US
103	Neely et al. (2013)	Research in Autism Spectrum Disorders	2 males	3-7	AS, PDD-NOS	Tablet	Generic	Prompting, interactive sequence	Academic, life	SSD	Reversal	School, home	US
104	Oakley et al. (2013)	Australasian Journal of Early Childhood		5-8	HFA, autism	PC, tablet	Generic	Interactive sequence	Academic			School	Australia
	Study 1		1 male							SSD	Exploratory		
	Study 2		1 male							SSD	Exploratory		
105	Palmen et al. (2012)	Developmental Neurorehabilitation	2 males 2 females	14-20	HFA	Small handheld	Special needs	Prompting	Life	SSD	Multiple baseline	Day centre	Netherlands
106	Palsbo & Hood-Szivek (2012)	The American Journal of Occupational Therapy	5 N/A	5-11	ASD	Robot	Special needs	Interactive agent	Academic	SSD	AB	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
107	Paterson & Arco (2007)	Behavior Modification	2 males	6-7	HFA	Conventional player	None	Prompting	Social communication, interaction	SSD	Multiple baseline	School	Australia
108	Pennington et al. (2011)	Assistive Technology Outcomes and Benefits	3 males	7-10	Autism	PC	Generic	Speech composition, speech generation	Academic	SSD	Multiple baseline	School	US
109	Pennington et al. (2014)	Education and Training in Autism and Developmental Disabilities	3 males	7-10	Autism	PC	Special needs	Sentence composition, speech generation	Academic	SSD	Multiple baseline	School	US
110	Pennington et al. (2012)	Education & Treatment of Children	1 male	7	Autism	PC	Special needs	Sentence composition, speech generation	Academic	SSD	Multiple probe	School	US
111	Plavnick (2012)	Research and Practice for Persons with Severe Disabilities	1 male	4	Autism	Small handheld	Generic	Prompting	Social communication, interaction	SSD	Multiple probe, alternating treatment	School	US
112	Pop et al. (2013)	Journal of Educational Computing Research	20 N/A	4-9	ASD	PC, robot	Generic	Interactive sequence, interactive agent	Social communication, interaction	GD	With control group, randomised	Therapy centre	Romania
113	Purrazzella & Mechling (2013)	Education and Training in Autism and Developmental Disabilities	1 male	20	Moderate autism	Tablet	Generic	Interactive sequence	Academic	SSD	Multiple probe	School, university	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
114	Rajendran & Mitchell (2000)	Computers & Education	2 males	23	AS	PC	Research	Interactive sequence	Social communication, interaction	SSD	AB	Home	UK
115	Rice et al. (2015)	Journal of Autism and Developmental Disorders	28 males 3 females	5-11	ASD	PC	Special needs	Interactive agent	Social communication, interaction	GD	With control group, randomised	School	US
116	Roche et al. (2014)	International Journal of Developmental Neuroscience	1 male	9	ASD	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Multiple baseline	Therapy centre	New Zealand
117	Russo-Ponsaran et al. (2014)	Journal of Mental Health Research in Intellectual Disabilities	3 males	9-11	ASD	PC	Special needs	Interactive sequence	Social communication, interaction	SSD	AB	N/A	US
118	Russo-Ponsaran et al. (2015)	Journal of Nonverbal Behavior	20 males 5 females	8-15	HFA	PC	Special needs	Interactive sequence	Social communication, interaction	GD	With control group, randomised	School, community, therapy centre	US
119	Saiano et al. (2015)	Annual International Conference of the IEEE Engineering in Medicine and Biology Society	4 males	19-31	ASD	PC	Research	Simulation	Life	GD	Without control group	N/A	Italy

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
120	Saiano et al. (2015)	Journal of Neuroengineering and Rehabilitation	6 males	19-44	ASD	PC	Research	Simulation	Life	SSD	AB	N/A	Italy
121	Sansosti & Powell-Smith (2008)	Journal of Positive Behavior Interventions	3 males	6-9	HFA, AS, PDD-NOS	PC	Generic	Prompting, interactive sequence	Social communication, interaction	SSD	Multiple baseline	School	US
122	Schlosser & Blischak (2004)	Journal of Speech, Language and Hearing Research	4 males	8-12	Mild autism	SGD	Special needs	Sentence composition, speech generation	Academic	SSD	Alternating treatment	School	US
123	Schlosser et al. (2007)	Research in Autism Spectrum Disorders	4 males 1 female	8-10	Autism	SGD	Generic	Sentence composition, speech generation	Social communication, interaction	SSD	Alternating treatment	School	US
124	Schneider et al. (2013)	Focus on Autism and other Developmental Disabilities	4 males	N/A	AS	PC	Generic	Sentence composition, speech generation	Academic	SSD	Alternating treatment	Home	US
125	Self et al. (2007)	Topics in Language Disorders	6 males 2 females	6-12	Autism	PC	Generic	Simulation	Life	GD	Without control group	School	US
126	Seok et al. (2015)	Education and Training in Autism and Developmental Disabilities	1 male	8	Autism	Tablet	Special needs	Interactive sequence	Academic	SSD	Alternating treatment	School	Korea
127	Serret et al. (2014)	Molecular Autism	31 males 2 females	6-17	Autism, AS, PDD-NOS	PC	Special needs	Simulation	Social communication, interaction	GD	Without control group	N/A	France

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
128	Sherer et al. (2001)	Behavior Modification	5 males	3-11	Autism, PDD-NOS	Conventional player	None	Prompting	Social communication, interaction	SSD	Multiple baseline, alternating treatment	Home, laboratory	US
129	Shih et al. (2015)	Research in Autism Spectrum Disorders	2 males	16-17	Moderate ASD, severe ASD	PC	Research	Collaborative games	Social communication, interaction	SSD	Reversal	School	Taiwan
130	Shih et al. (2014)	Research in Autism Spectrum Disorders	2 males	17	ASD	PC	Research	Prompting	Social communication, interaction	SSD	Multiple probe	School	Taiwan
131	Silver & Oakes (2001)	Autism: The International Journal of Research and Practice	22 N/A	12-18	Autism, AS	PC	Special needs	Interactive sequence	Social communication, interaction	GD	With control group, randomised	School	UK
132	Simpson & Keen (2010)	Journal of Developmental and Physical Disabilities	3 males	3-4	ASD	IDW	Generic	Interactive sequence	Academic	SSD	Multiple baseline	Therapy centre	Australia
133	Simpson et al. (2015)	Journal of Intellectual & Developmental Disability	17 males 5 females	3-8	ASD	PC	Generic	Interactive sequence	Academic	GD	Without control group	School	Australia
134	Simpson et al. (2004)	Education and Training in Autism and Developmental Disabilities	2 males 2 females	5-6	Mild autism, moderate autism	PC	Generic	Prompting, interactive sequence	Social communication, interaction	SSD	Multiple probe	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
135	Sitdhisanguan et al. (2012)	Personal and Obiquitous Computing	20 males	3-5	LFA	PC	Research	Interactive sequence	Academic	GD	Without control group	Therapy centre	Thailand
136	Smith et al. (2013)	Research in Autism Spectrum Disorders	3 males	11-12	Autism	Tablet	Generic	Interactive sequence	Academic	SSD	Multiple probe	School	US
137	Smith et al. (2014)	Journal of Autism and Developmental Disorders	20 males 6 females	18-31	ASD	PC	Special needs	Interactive agent	Life	GD	With control group, randomised	Laboratory	US
138	Smith et al. (2015)	Research in Autism Spectrum Disorders	3 males	15-16	ASD	PC, small handheld	Generic	Prompting	Life	SSD	Multiple probe	Day centre	US
139	Soares et al. (2009)	Behavioral Interventions	1 male	13	AS	PC	Generic	Augmented information	Academic, life	SSD	Reversal	School	US
140	Spooner et al. (2014)	Research and Practice for Persons with Severe Disabilities	4 males	8-12	Autism	Tablet	Special needs	Interactive sequence	Academic	SSD	Multiple probe	School	US
141	Spooner et al. (2015)	Research and Practice for Persons with Severe Disabilities	2 females	7-8	ASD	Tablet	Special needs	Interactive sequence	Academic	SSD	Multiple probe	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
142	Spriggs et al. (2015)	Journal of Autism and Developmental Disorders	3 males' 1 female	17-19	ASD, PDD-NOS	Tablet	Special needs	Prompting, augmented information	Academic, life	SSD	Multiple probe	School	US
143	Srinivasan et al. (2013)	Perceptual and Motor Skills	1 male	7	Autism	Robot	Research	Interactive agent	Social communication, interaction, life	SSD	AB	N/A	US
144	Srinivasan et al. (2015)	Research in Autism Spectrum Disorders	32 males 4 females	5-12	ASD	Robot	Research	Interactive agent	Social communication, interaction, life	GD	With control group, randomised	N/A	US
145	Stasolla et al. (2014)	Research in Autism Spectrum Disorder	2 males	7-8	Severe ASD	PC	Generic	Interactive sequence	Academic, life	SSD	Alternating treatment	School	Italy
146	Stichter et al. (2014)	Journal of Autism and Developmental Disorders	11 males	11-14	HFA	PC	Research	Simulation	Social communication, interaction	GD	Without control group	School	US
147	Still et al. (2015)	Research in Autism Spectrum Disorders		3-12	ASD	Tablet	Research	Interactive sequence	Social communication, interaction, academic			School, home	UK
	Study 1		6 males 2 females							GD	Without control group		
	Study 2		2 males 1 female							SSD	Multiple probe		

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
148	Strickland et al. (2013)	Journal of Autism and Developmental Disorders	22 males	16-19	HFA, AS	PC	Special needs	Interactive sequence, interactive agent, simulation	Life	GD	With control group, randomised	Home, university	US
149	Takezawa et al. (2012)	Industrial Engineering & Management Systems	1 male	8	ASD	PC	Research	Interactive sequence	Social communication, interaction	SSD	AB	School, laboratory	Japan
150	Tanaka et al. (2010)	Journal of Child Psychology and Psychiatry	62 males 17 females	N/A	Autism, AS, PDD-NOS	PC	Research	Interactive sequence	Social communication, interaction	GD	With control group, randomised	Home	N/A
151	Tapus et al. (2012)	Interaction Studies	4 males	2-6	Moderate autism, severe autism	Robot	Research	Interactive agent	Social communication, interaction	SSD	Alternating treatment	Laboratory	Romania
152	Thomeer et al. (2011)	Focus on Autism and other Developmental Disabilities	8 males 3 females	7-12	Autism, AS, PDD-NOS	PC	Special needs	Interactive sequence	Social communication, interaction	GD	Without control group	N/A	US
153	Thomeer et al. (2001)	Journal of Autism and Developmental Disorders	38 males 5 females	7-12	HFA	PC	Special needs	Interactive sequence	Social communication, interaction	GD	With control group, randomised	Laboratory	US
154	Tjus et al. (2001)	Autism: The International Journal of Research and Practice	9 males 2 females	N/A	Autism	PC	Research	Prompting	Social communication, interaction, academic	GD	Without control group	School	Sweden

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
155	Tjus et al. (2004)	Journal of Cognitive and Behavioral Psychotherapies	10 males 3 females	4-11	Autism	PC	Research	Sentence composition, speech generation	Academic	GD	Without control group	N/A	N/A
156	Travers et al. (2011)	Education and Training in Autism and Developmental Disabilities	17 N/A	3-6	Autism	PC	Research	Interactive sequence	Academic	GD	Without control group	School	US
157	Ulke-Kurkcuoglu et al. (2015)	Educational Sciences - Theory & Practice	4 males	4-10	ASD	PC	Generic	Augmented information	Social communication, interaction, academic	SSD	Multiple probe	Therapy centre	Turkey
158	Van der Meer et al. (2011)	Journal of Special Education Technology	1 male	13	Autism	Small handheld	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Multiple probe	School	New Zealand
159	Van der Meer et al. (2013)	Augmentative and Alternative Communication	1 male 1 female	10-11	Autism	Tablet, small handheld	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Alternating treatment	School, home	New Zealand
160	Van der Meer et al. (2014)	Clinical Case Studies	1 male	10	ASD	Tablet	Special needs	Sentence generation, speech generation	Social communication, interaction	SSD	AB	Home	New Zealand
161	Van Laarhoven & Van Laarhoven-Myers (2006)	Education and Training in Autism and Developmental Disabilities	1 male	18	Autism	PC	Generic	Prompting	Life	SSD	Alternating treatment	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
162	Vanderborght et al. (2012)	Interaction Studies	2 males 2 females	4-8	Moderate autism	Robot	Research	Interactive agent	Social communication, interaction	SSD	Alternating treatment	Therapy centre	Romania
163	Wainer et al. (2014)	IEEE Transactions on Autonomous Mental Development	5 males 1 female	8-9	Autism	Robot	Research	Interactive sequence, interactive agent	Social communication, interaction	SSD	Reversal	School	UK
164	Wang & Reid (2013)	The Scientific World Journal	3 males 1 female	6-8	Autism, PDD-NOS	PC	Research	Simulation	Academic	SSD	Multiple baseline	Home	Canada
165	Warren et al. (2015)	Journal of Autism and Developmental Disorders	6 males	2-4	ASD	Robot	Research	Interactive agent	Social communication, interaction	GD	Without control group	Laboratory	US
166	Weinger & Depue (2011)	Child & Family Behavior Therapy	5 males 1 female	7-11	ASD	PC	Special needs	Interactive sequence	Social communication, interaction	GD	With control group, not randomised	Home	US
167	Weng & Bouck (2014)	Research in Autism Spectrum Disorders	3 males	15-17	Autism	Tablet	Generic	Prompting	Life	SSD	Multiple probe	School, community	US
168	Whalen et al. (2006)	The Journal of Speech and Language Pathology		3-4	Autism	PC	Special needs	Interactive sequence	Social communication, interaction, academic			Home	US
	Study 1		4 N/A							GD	Without control group		
	Study 2		4 N/A							SSD	Multiple baseline		

(continued)

Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
169	Whalen et al. (2010)	Autism: The International Journal of Research and Practice	47 N/A	3-6	Autism	PC	Special needs	Interactive sequence	Social communication, interaction, academic, life	GD	With control group, randomised	School	US
170	Whitcomb et al. (2011)	Journal of Developmental and Physical Disabilities	1 male	9	Autism	PC	Special needs	Interactive sequence	Academic	SSD	Multiple baseline	School	US
171	Williams et al. (2002)	Autism: The International Journal of Research and Practice	8 N/A	3-5	Autism	PC	Research	Interactive sequence	Academic	GD	Without control group	School	UK
172	Williams et al. (2004)	Research in Developmental Disabilities	4 males 1 female	8-13	ASD	PC	Research	Interactive agent	Academic	GD	Without control group	School	US
173	Williamson et al. (2013)	Assistive Technology	2 males 1 female	N/A	Autism	Conventional player	None	Prompting	Social communication, interaction	SSD	Multiple baseline	School	US
174	Xin (2014)	Studies in Literature and Language	4 males	13-14	ASD	PC	Generic	Interactive sequence	Academic	SSD	Multiple baseline	School	US
175	Xin & Leonard (2015)	Journal of Autism and Developmental Disorders	2 males 1 female	10	ASD	Tablet	Special needs	Sentence composition, speech generation	Social communication, interaction	SSD	Multiple baseline	School	US

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Table B1 (*continued*)

	Study	Journal	Participants' characteristics			Technology			Target skill	Research design		Setting	Country
			N/gender	Age	Diagnosis	HW	SW	MoD					
176	Xin & Sutman (2011)	Teaching Exceptional Children	1 male 1 female	9	ASD	IDW	Generic	Prompting, interactive sequence	Social communication, interaction	SSD	AB	School	US
177	Yakubova & Taber-Doughty (2013)	Journal of Autism and Developmental Disorders	2 males	16-19	Mild autism, moderate autism	IDW	Generic	Prompting	Life	SSD	Multiple probe	School	US
178	Yaw et al. (2011)	Journal of Behavioral Education	1 male	12	Autism	PC	Generic	Interactive sequence	Academic	SSD	Multiple baseline	School	US

Appendix C

List of references of the reviewed studies

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Appendix D

Evaluation tools for determining EBP in ASD

Adopted from “Development of the Evaluative Method for Evaluating and Determining Evidence-Based Practices in Autism,” by B. Reichow, F. R. Volkmar, and D. V. Cicchetti, 2008, *Journal of Autism and Developmental Disorders, 38*, pp. 1313-1315. Copyright 2007 by Springer Science+Business Media.

Group research	
Quality indicator	Definition
Primary quality indicators	
Participant characteristics	Age and gender were provided for all participants, specific diagnostic information was provided for all participants with autism, if applicable, standardized test scores were provided, and information on the characteristics of the interventionist was provided
Independent variable	Information about the treatment was provided with replicable precision (if a manual was used, this was always given a high quality rating)
Comparison condition	The conditions for the comparison group were defined with replicable precision, including, at a minimum, a description of any other interventions participants received
Dependent variable	Dependent measures were described with operational and replicable precision, showed a clear link to the treatment outcome, and were collected at appropriate times
Link between research question and data analysis	Data analyses were strongly linked to the research question(s) and the data analysis used correct units of measure (i.e., child level, teacher level, etc.) on all variables
Use of statistical tests	Proper statistical analyses were conducted for each statistical measure with an adequate power and a sample size of $n \geq 10$
Secondary quality indicators	
Random assignment	Participants were assigned to groups using a random assignment procedure
Interobserver agreement	IOA was collected across all conditions, raters, and participants with inter-rater agreement at or above .80, and a minimum of Good reliability ($\kappa \geq .60$). Psychometric properties of standardized tests were reported and were equal or greater than .70 agreement with a $\kappa \geq .40$
Blind raters	Raters were blind to the treatment condition of the participants
Fidelity	Procedural fidelity or treatment fidelity was continuously assessed across participants, conditions, and implementers, and if applicable, had measurement statistics at or greater than .80
Attrition	Articulation was comparable (did not differ between groups by more than 25%) across conditions and less than 30% at the final outcome measure
Generalization and/or maintenance	Outcome measures were collected after the final data collection to assess generalization and/or maintenance
Effect size	Effect sizes were reported for at least 75% of the outcome measures and were equal or greater than .40
Social validity	The study contained at least four of the following; (a) DVs were socially important (i.e., would society value the changes in outcome of the study), the (b) intervention was time and cost effective (i.e., did the ends justify the means), (c) comparisons were made between individuals with and without disabilities, (d) the behavioral change was large enough for practical value (clinically significant), (e) consumers were satisfied with the results, (f) people who typically come in contact with the participant manipulated the IVs, (g) the study occurred in natural contexts

Figure D1. Definition of group research quality indicators.

Single subject research	
Quality indicator	Definition
Primary quality indicators	
Participant characteristics	Age and gender were provided for all participants, specific diagnostic information was provided for all participants with autism, if applicable, standardized test scores were provided, and information on the characteristics of the interventionist was provided
Independent variable	Information about the treatment was provided with replicable precision (if a manual was used, this was always given a high quality rating)
Dependent variable	Dependent measures were described with operational and replicable precision, showed a clear link to the treatment outcome, and were collected at appropriate times
Baseline condition	All baselines (a) encompassed at least three measurement points, (b) appeared through visual analysis to be stable, (c) had no trend or a counter therapeutic trend, and (d) were operationally defined with replicable precision
Visual analysis	All relevant data for each participant was graphed. Inspection of the graphs revealed (a) all data appeared to be stable (level and/or trend), (b) contained less than 25% overlap of data points between adjacent conditions, unless behavior was at ceiling or floor levels in previous condition, and (c) showed a large shift in level or trend between adjacent conditions which coincided with the implementation or removal of the IV (note, if there was a delay in change at the manipulation of the IV, the delay was similar across different conditions and/or participants [±50% of delay])
Experimental control	There were (a) at least three demonstrations of the experimental effect, (b) at three different points in time, and (c) changes in the DVs covaried with the manipulation of the IV in all instances of replication (note, if there was a delay in change at the manipulation of the IV, the delay was similar across different conditions or participants [±50% of delay]).
Secondary quality indicators	
Interobserver agreement	IOA was collected on at least 20% of sessions across all conditions, raters, and participants with inter-rater agreement at or above .80
Kappa	Kappa was calculated on at least 20% of sessions across all conditions, raters, and participants with a score at or greater than .60 (Good reliability)
Fidelity	Procedural fidelity and/or treatment fidelity was continuously assessed across participants, conditions, and implementers with reliability at or greater than .80
Blind raters	Raters were blind to the treatment condition of the participants
Generalization and/or maintenance	Outcome measures were collected after the conclusion of the intervention to assess generalization and/or maintenance
Social validity	The study contained at least four of the following; (a) DVs were socially important (i.e., would society value the changes in outcome of the study), the (b) intervention was time and cost effective (i.e., did the ends justify the means), (c) comparisons were made between individuals with and without disabilities, (d) the behavioral change was large enough for practical value (clinically significant), (e) the consumers were satisfied with the results, (f) people who typically come in contact with the participant manipulated the IVs, (g) the study occurred in natural contexts

Figure D2. Definition of single subject research quality indicators.

Strength of research report	Group research	Single subject research
Strong	Received high quality ratings on all primary quality indicators and showed evidence of four or more secondary quality indicators	Received high quality ratings on all primary quality indicators and showed evidence of three or more secondary quality indicators
Adequate	Received high quality ratings on four or more primary quality indicators with no unacceptable quality ratings on any primary quality indicators, and showed evidence of at least two secondary quality indicators	Received high quality ratings on four or more primary quality indicators with no unacceptable quality ratings on any primary quality indicators, and showed evidence of at least two secondary quality indicators
Weak	Received fewer than four high quality ratings on primary quality indicators or showed evidence of less than two secondary quality indicators	Received fewer than four high quality ratings on primary quality indicators or showed evidence of less than two secondary quality indicators

Figure D3. Guidelines for the determination of research report strength.

Level of EBP	Criteria (treatment must meet at least one criterion, can meet multiple criteria)
Established EBP	At least five single subject studies of strong research report strength meeting the following criteria
	Conducted by at least three different research teams
	Conducted in at least three different locations
	Total sample size of at least 15 different participants across studies
	At least 10 single subject studies of at least adequate research report strength meeting the following criteria
	Conducted by at least three different research teams
	Conducted in at least three different locations
	Total sample size of at least 30 different participants across studies
	At least two group experimental design studies of strong research report strength conducted in separate laboratories by separate research teams
	At least four group experimental design studies of at least adequate research report strength conducted in at least two different laboratories by separate research teams
	One group experimental design study of strong research report strength and three single subject studies of strong research report strength
	Two group experimental design studies of at least adequate research report strength and three single subject studies of strong research report strength
	One group experimental design study of strong research report strength and six single subject studies of at least adequate research report strength
	Two group experimental design studies of at least adequate research report strength and six single subject studies of at least adequate research report strength
Promising EBP	At least three single subject studies of at least adequate research report strength meeting the following criteria
	Conducted by at least two different research teams
	Conducted in at least two different locations
	Total sample size of at least nine different participants across studies
	At least two group experimental design studies of at least adequate research report strength (can be conducted by the same research team in the same location)

Figure D4. Criteria for treatments to be considered EBP.

Appendix E

Brief questionnaire administered to parents, teachers, psychologists and the school head for the social significance of Study 3

(the form for parents is shown here)

Editar este formulario

Imitación y atención conjunta en TEA

Entrevista a familiares

*Obligatorio

Datos de identificación

Nombre y apellidos de la persona que responde el cuestionario *

Nombre y apellidos de la persona con TEA *

Relación con la persona con TEA (p.e. padre/madre, hermano/a, abuelo/a) *

Imitación

Definimos imitación como una conducta mediante la cual una persona observa y replica el comportamiento de otra persona o cosa. A partir de esta definición, indique el grado de acuerdo que presenta ante cada una de las afirmaciones que aparecen a continuación considerando su familiar con TEA (hijo/a, nieto/a, hermano/a, etc) 1. Totalmente en desacuerdo; 2. En desacuerdo; 3. Ni de acuerdo ni en desacuerdo; 4. De acuerdo: 5. Totalmente de acuerdo

La imitación es una habilidad importante para que mi familiar aprenda *

	1	2	3	4	5	
Totalmente en desacuerdo	○	○	○	○	○	Totalmente de acuerdo

Que mi familiar imite gestos y/o sonidos es importante para su aprendizaje *

	1	2	3	4	5	
Totalmente en desacuerdo	○	○	○	○	○	Totalmente de acuerdo

Que mi familiar aprenda nuevos conceptos puede depender de sus habilidades de imitación *

1 2 3 4 5

Totalmente en desacuerdo ◯ ◯ ◯ ◯ ◯ Totalmente de acuerdo

Atención conjunta

Definimos atención conjunta como el objetivo compartido por dos personas hacia un objeto (p.e. un juguete, una tercera persona). La atención conjunta se consigue cuando una persona alerta a otra persona sobre un objeto mediante la mirada, la conducta de señalar u otras indicaciones verbales o no verbales. A partir de esta definición, indique el grado de acuerdo que presenta ante cada una de las afirmaciones que aparecen a continuación considerando su familiar con TEA (hijo/a, nieto/a, hermano/a, etc) 1. Totalmente en desacuerdo; 2. En desacuerdo; 3. Ni de acuerdo ni en desacuerdo; 4. De acuerdo: 5. Totalmente de acuerdo

La atención conjunta es una habilidad importante para que mi familiar aprenda *

	1	2	3	4	5	
Totalmente en desacuerdo	◯	◯	◯	◯	◯	Totalmente de acuerdo

Que mi familiar desarrolle habilidades de atención conjunta es importante para su aprendizaje *

	1	2	3	4	5	
Totalmente en desacuerdo	◯	◯	◯	◯	◯	Totalmente de acuerdo

Que mi familiar aprenda nuevos conceptos puede depender de sus habilidades de atención conjunta *

	1	2	3	4	5	
Totalmente en desacuerdo	◯	◯	◯	◯	◯	Totalmente de acuerdo

Tecnología

Indique el grado de acuerdo que presenta ante cada una de las afirmaciones que aparecen a continuación considerando su familiar con TEA (hijo/a, nieto/a, hermano/a, etc) 1. Totalmente en desacuerdo; 2. En desacuerdo; 3. Ni de acuerdo ni en desacuerdo; 4. De acuerdo: 5. Totalmente de acuerdo

A mi familiar le gustan las nuevas tecnologías *

	1	2	3	4	5	
Totalmente en desacuerdo	◯	◯	◯	◯	◯	Totalmente de acuerdo

Las nuevas tecnologías pueden ser beneficiosas para el aprendizaje de mi familiar *

	1	2	3	4	5	
Totalmente en desacuerdo	○	○	○	○	○	Totalmente de acuerdo

Considero beneficioso el uso de nuevas tecnologías si mediante ellas pueden mejorar las habilidades de imitación y atención conjunta de mi familiar *

	1	2	3	4	5	
Totalmente en desacuerdo	○	○	○	○	○	Totalmente de acuerdo

Notas

Enviar

Appendix F

Informed consent signed by pupils' parents for their participation in Study 3

VNIVERSITAT ID VALÈNCIA

Pictogram Room

Consentimiento informado para la participación en el estudio Pictogram Room

Yo……………………………………………………………………………………, con DNI……………………, en calidad de ………………………. (padre, madre, tutor legal) del/ de la alumno/a …….

- He leído la hoja de información del estudio Pictogram Room que se me ha facilitado (Anexo I).
- He tenido oportunidad de realizar preguntas acerca del estudio a la persona responsable de la investigación cuyo contacto se me ha facilitado.
- He recibido suficiente información sobre el estudio.
- Entiendo que la participación es voluntaria.
- Entiendo que la persona que participa puede retirarse del estudio en cualquier momento sin tener que ofrecer explicaciones por ello y sin que le afecte negativamente en sentido alguno.

Y, por lo tanto:

- Acuerdo autorizar su participación en el estudio Pictogram Room, que se realizará en las instalaciones del CEIP Benjamín Benlloch de Manises.
- Permito que el equipo educativo del centro y/o los investigadores le realicen pruebas estandarizadas que evalúen sus logros.
- Con el objeto de su análisis posterior para la investigación, permito la grabación en vídeo de su participación durante las sesiones del estudio. El uso de dichas grabaciones para cualquier otro propósito más allá del estrictamente ligado a este trabajo (uso en medios de comunicación, congresos, tareas docentes…), requeriría que se me solicitara un nuevo consentimiento.

En (lugar)…………………………………, a (día)……., de (mes)………………………., de (año)………..

Firma del tutor del participante: Firma del investigador/a:

VNIVERSITAT DE VALÈNCIA

Pictogram Room

Anexo I. Información sobre el estudio Pictogram Room

¿Qué es Pictogram Room?

Pictogram Room es un conjunto de video juegos especialmente diseñados para entrenar habilidades relevantes para la intervención en personas con trastorno del espectro autista (TEA), tal es el caso de la comprensión del lenguaje corporal, el reconocimiento de sí mismo/a, la imitación o la atención conjunta. Se trata de destrezas claves para el desarrollo que se pueden abordar de forma lúdica con Pictogram Room junto con el apoyo de profesionales y también en compañía de sus compañeros/as (con y sin TEA). Los juegos de Pictogram Room están pensados para aprovechar los puntos fuertes de cada alumno/a, y se organizan dentro de cuatro bloques: el cuerpo, las posturas, imitación y señalar. Todas las actividades cuentan con una estructura común y se puede jugar con ellas tanto individual (el alumno/a solo) (Figura 1) como colectivamente (alumno/a-maestro/a; alumno/a-alumno/a) (Figura 2), pudiendo personalizarse aspectos visuales (fotos, vídeos) y auditivos (volumen, música) de las mismas.

¿Qué tecnología usa Pictogram Room?

Mediante un sistema de proyección, y a través del reconocimiento de su cuerpo, se consigue reproducir la imagen del propio jugador como si fuese un espejo, pudiendo visualizar bien su imagen real (Figura 1), o bien su representación mediante esqueleto (Figura 2). Para su funcionamiento se necesita un PC con Windows 7 o Windows 8, el sensor Kinect para Windows o Xbox y una superficie de proyección (televisión, pantalla o pared) en la que visualizar Pictogram Room.

Figura 1. Juego 'Moverse con luces'

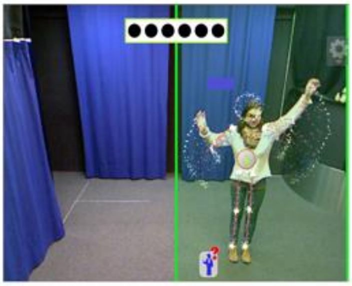
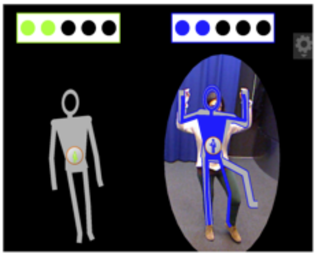


Figura 2. Juego 'Imitar posturas'



Para más información, se puede consultar una guía pedagógica que se entrega y también visitar la página web http://www.pictogramas.org, desde la cual se puede descargar Pictogram Room de forma gratuita.

¿En qué consiste el estudio que se va a hacer con Pictogram Room?

Responsable del estudio y persona de contacto

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Objetivo del estudio

Mejorar habilidades de comunicación e interacción social -como atención conjunta e imitación- mediante el uso de Pictogram Room.

Procedimiento*

La investigadora acudirá al centro educativo de su hijo/a tres días a la semana a partir de febrero de 2015. Durante los primeros días se adoptará una decisión a partir del asesoramiento de las profesionales del Aula de Comunicación y Lenguaje que mejor conocen a su hijo/a respecto a qué habilidades serán entrenadas con cada alumno/a mediante Pictogram Room de acuerdo con sus características. Esta decisión estará basada en los objetivos curriculares previamente establecidos para cada caso y el potencial que tienen los juegos de Pictogram Room para poder cubrirlos. Todos los martes, miércoles y viernes, cada alumno asistirá al aula de informática acompañado por la investigadora y un/a profesional de referencia del Aula CyL para completar una sesión de aproximadamente 20 minutos. Esta sesión, que será video grabada, consistirá en 10 minutos de interacción con Pictogram Room, más 10 minutos de evaluación respecto a las habilidades entrenadas. Se estima que cada alumno/a completará un total de 18 sesiones, repartidas en 6 semanas.

*Nota: toda la información contenida en el procedimiento está sujeta a cambios debidos a las posibles faltas de asistencia al centro por parte de alumnado, equipo docente o investigador; la duración de la sesión podría verse afectada por el deseo o necesidad de finalizarla antes del tiempo preestablecido.