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Testing Literacy Educational Software to Develop Design Guidelines for Children with Autism

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ABSTRACT

Multimedia computer programmes have been found to facilitate learning in children with Autistic Spectrum Disorders (ASD). However, the effectiveness of these resources is limited due to poor design or a lack of consideration of the ASD cognitive profile, particularly at the lower functioning end of the spectrum. This article attempts to tackle the problem of the lack of design guidelines, with the aim of facilitating the development of effective educational programmes for children with severe ASD. The case study reported here evaluated two literacy educational computer programmes, by observing five low-functioning children with ASD, compared to five neurotypical children (control cases). The two types of reading-support software contrasted in the study presented different characteristics. The children's data analysed here concern observations of child–software interactive sessions based on video recordings and coded for attention deployment to each programme, including motivation and engagement indicators.

KEYWORDS

Autism; Autistic Spectrum Disorders (ASD); computer technology; guidelines; learning disabilities; literacy software; multimedia technology; Reading

Introduction

Finding the right methodology for the design of effective educational computer software to support various aspects of learning in special populations can be a challenging process, as there are no systematic or clearly laid down procedures to support this process. Several studies have claimed that the use of educational computer programmes can support and promote learning in children with ASD. Swenson and Kingman (1981) were the first to formally suggest the potential of computing technology in special education. Computer technology fascinates children with ASD and has been used to promote various aspects of learning, communication and social skills (Chen & Bernard-Opitz, 1993; Heimann, Nelson, Gillberg, & Karnevik, 1993; Heimann, Nelson, Tjus, & Gillberg, 1995; Heimann, Tjus, & Nelson, 1993; Kientz & Abowd, 2008; Moore & Calvert, 2000; Tseng & Yi-Luen, 2011; Whalen, Massaro, & Franke, 2009; Williams, Callaghan, & Coughlan, 2002).

Computing technology has been extensively employed to promote education and entertainment for children with autism (Bernard-Opitz, Ross, & Tuttas, 1990; Moore & Calvert, 2000; Panyan, 1984; Russo, Koegei, & Lovaas, 1978). These tools have been proven to be beneficial for children with autism and other associated disabilities (Heimann et al., 1995;

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Sansosti, Doolan, Remaklus, Krupko, & Sansosti, 2015; Tseng & Yi-Luen, 2011; Whalen et al., 2009), yet there are scant methodological guidelines and little standardisation available in the public domain to facilitate the design of effective education computer software for children with autism, particularly at the lower functioning end of the spectrum Fletcher-Watson (2014) reviews the state of the art in Computer Aided Learning (CAL) in autism education calling for greater theoretical underpinning.

Theoretical Framework and Review of Literature

Autistic Spectrum Disorders (ASD), also known as infantile autism, childhood autism or classic autism is a disorder characterised by a triad of impairments affecting language and communication, imagination and flexibility of thought and socialisation (Wing, 1996). Autism was first identified and documented by Kanner (1943) and Asperger (1944). The current definition of the condition in terms of 'Autistic Spectrum Disorders' carries the implication of a range of conditions, from Asperger's syndrome (high functioning autism, in which intellectual abilities are intact or only marginally reduced) to severe autism (classical autism, often characterised by lack or severe limitation of speech and mental disability), with a range of severity along the continuum between the two (Kent et al., 2013). Most research on learning and cognitive development in children with ASD has focused on the higher functioning end of the spectrum, although ≥70% of individuals affected by the disorder are intellectually disabled (Baird et al., 2006).

Heimann, Nelson et al. (1993, 1995) and Heimann, Tjus et al. (1993) suggested that a planned intervention, using computer instructed learning that includes a highly motivating and interactive multimedia environment will often improve reading, writing and communication skills when teaching children with ASD or multiple handicaps (cerebral palsy and mental retardation). In the *DELTA Messages Project*, Heimann, Tjus et al. (1993) undertook the evaluation of the impact of interactive multimedia computer programmes on facilitating the acquisition of reading, writing and overall communication skills in children who were experiencing significant delays in their communicative development. This study noted that, of the first twenty-three children who completed their training (eleven with autism, six with dyslexia, four with hearing impairments and two with cerebral palsy), a significant improvement in reading was observed specifically in the children with ASD.

In a similar study, Heimann et al. (1995) investigated the effect of using an interactive and child-initiated microcomputer programme (*Alpha*) to teach reading and communication skills to three groups of children (children with ASD, children with mixed handicaps and typically developing preschool children). This study recorded that the children with ASD increased both their reading and phonological awareness through their use of the *Alpha* programme, which utilised a multi-channel feedback (voice, animation, video and sign language) model. The benefit of exploring all of the varied media used in these programmes to support learning is that they may prove to have the capacity to cater for different levels of severity of ASD.

In a study involving a small sample ($N = 13$) of children with autism, mixed handicaps and preschool children, Tjus, Heimann, and Nelson (1998) hypothesised that children with ASD and various cognitive disabilities might benefit from a strategy that combined a motivating multimedia programme and positive interaction with the teacher. In a quasi-experimental study, the authors showed that the children with ASD read more rapidly following the intervention. Their study employed the *Rare Event Learning* (REL) theory (Nelson, Heimann, & Tjus, 1997), which suggested that it is rare to have all of the relevant conditions (cognitive, social, motivational and linguistic conditions) needed to facilitate/maximise learning. The authors later tried to demonstrate and refine the REL theory (Tjus & Heimann, 2001) and they found that children showed increased word acquisition (word spoken) when all relevant conditions were satisfied in multimedia programme and interaction, thus providing support to their model.

Unlike other studies, the REL theory discussed above examined ways of applying and optimising reading in children with ASD through a model of learning and through teaching strategies. However, these strategies lacked a comprehensive application format, which could only be achieved if the principles proposed were developed with greater detail and depth. Moore and Calvert (2000) echoed this view in suggesting that carefully developed computer software can create an interesting and simulating environment for children with ASD, and thus promote their learning of vocabulary. Moreover, they also suggested that computers are a cost-effective way of educating children who require one to one assistance in order to learn. Williams et al. (2002) evaluated the development of reading skills in a small sample of 3- to 5-year-old children with ASD ($N = 8$) using both computer-assisted learning and book-based learning. This study found that five out of eight children could reliably identify at least three words through the use of CAL. The children with ASD spent more time reading the material when they accessed it through a computer than when they utilised books, which the authors interpreted as evidence that children with ASD were less resistant to using computer technology than books in learning situations.

Finally Robins, Dickerson, Stribling, and Dautenhahn (2004) and Robins, Dautenhahn, te Boekhorst, and Billard (2005) emphasised the benefits of computers in supporting learning of predefined behaviours in children with ASD. These researchers successfully employed robots as a means to teach imitation skills and simple coordinated behaviours to children with ASD as part of an education therapy. Goldsmith and LeBlanc (2004) compared a range of intervention strategies including CAL and robotics with limited success.

The existing literature about designing computer software for children with ASD suffers from a number of limitations, where the emphasis has been more on demonstrating that educational computer programmes can be of benefit, and less upon developing much needed guidelines, principles and methodological frameworks. The design of better educational computer programmes fitting specific cognitive profiles and learning styles for children with different types of special needs, and specifically with ASD is needed. Thus, a first step in this direction would be taking into account strengths and weaknesses which characterise different phenotypes. Stokes (2016) has trialled individualised software in schools with a number of children with ASD. In this article we examine the use of general learning software in learning situations with ASD students.

Baron-Cohen, Leslie, and Frith (1985) stated that many of the problems that children with ASD encounter when learning are often not adequately addressed by current educational interventions. Powell (2001) also suggested that there is a limited understanding of the ASD learning style/s amongst some professionals who are involved in educational structures including this population. They attributed the failure of children with ASD to learn a variety of skills to a lack of understanding of their learning requirements. More specifically, Powell and Jordan (1997) highlighted that to support learning in children with ASD, it is essential to understand their *strengths* as much as their behavioural and developmental challenges such as low attention span, low motivation, atypical perception and communication difficulties.

Furthermore, little consideration has been given to the issues that may affect the learning process specifically when atypical children use computer technology. If individuals with ASD are to benefit from educational computer software and Adaptive Computer Systems (ACS), then the software designers need to take into consideration both strengths and weaknesses of the ASD profile. Nation, Clarke, and Wright (2006) defined ASD on the basis of the language and cognitive profile.

For the reasons illustrated above, it is of paramount importance to develop methodological guidelines for designers of computer programmes based on a new and more informed framework taking into account the population's cognitive profile in terms of strengths and weaknesses.

Hypotheses/Research Questions

The present study aims to provide an initial contribution to filling this gap and propose a first set of guidelines based on an empirical study with children with ASD. More specifically, the aim of the present study is twofold:

(a) To extend the above research to low-functioning (rather than high-functioning) children with ASD, by investigating if computer technology assists them in vocabulary acquisition based on word recognition/reading; and
(b) To propose how educational computer programmes may be developed to accommodate the strengths and weaknesses of children with ASD. The data presented here concern a pre/post treatment study contrasting the outcomes from two different educational programmes (treatment), also involving an observational analysis of the ASD user's interaction with the software during the treatment phase.

In the this study, besides the general research question that computer programmes will be associated with word learning in children with ASD, three specific empirical hypotheses were tested:

(1) There will be less sustained attention when children with ASD use a computer programme that contains little or no animation;
(2) Children with ASD will show less motivation/responsiveness when fewer external prompts are provided (by the computer programme, or physical and verbal prompts by the teacher/facilitator); and
(3) Episodes of boredom and stress (a lack of engagement) will be more frequent when children with ASD use a computer programme containing high levels of interactivity (Tuedor, 2006).

Method

The collection of cases for this study included five children with ASD aged 5–10 years (chronological age), who were all nonverbal and non-readers. They all attended a special needs school in London (UK) as a result of their diagnosis, and took part in activities in the ASD unit. All of the children had been diagnosed with low-functioning ASD as confirmed in the school's records. In order to have a control comparison sample of cases, five typically developing children were tested (TD henceforth), all attending a mainstream nursery school in

London (UK). The TD children were at the pre-reader stage, from age 3½ to 5 years. In contrast, children with ASD (at the low-functioning end of the autistic spectrum) typically are at the pre-reader stage from ages 6–12 or even later (with some who may never progress beyond the pre-reader stage) Nation et al. (2006).

Design

This study adopted a mixed methodology within a pre/post treatment design. An experimental manipulation involved children's vocabulary being tested pre- and post-intervention, with the intervention being the use of two different types of educational computer programmes (see Materials below) used on different occasions. The observational technique was used to analyse the intervention phase (see Observation Coding Scheme).

Procedure

The overall duration of the test was approximately 15 min. Children were tested with regard to the words known before and after the intervention phase. Two to three words were tested during the pre- and post-test, depending on each participant's attention span. Extensive verbal support was provided to alleviate problems of motivation during the test, as suggested by the literature (Peeters, 2001; Powell, 2001; Wing, 1996). Symbols from the *Widigit 2000* programme version 2.615 and pictures from the Picture Exchange Communication System (PECS) were employed as communication devices in conducting the vocabulary tests. The words tested were chosen randomly from the words taught by the computer software. The choice of the words taught and tested were based on two considerations; 'visual' or 'concrete' words (i.e. words such as 'bus' or 'biscuit') and familiar or everyday words (words the children were familiar with such as 'drink' or 'sleep'). Based on their knowledge of the children, the school teaching assistants gave advice on the appropriateness of the words to include or exclude from the experiment.

During the intervention phase, two reading computer programmes (the independent variable) for children with ASD were employed (see Materials). The children were video-recorded using both programmes for 5–15 min sessions. The lengths of the sessions were constant for the TD children but it varied for the children with ASD, due to individual differences between the children and their degree of restlessness. Teaching assistants were used as facilitators with the ASD sample. Their views and opinions were sought in order to facilitate communication and to disambiguate interpretation of incidents. Notes were also made about the dispositions and actions of the children whilst conducting this study.

The video recordings were edited from two cameras that were synchronised and displayed on a split screen. The first camera focused on the computer interface, whilst the second showed the child using the computer programme. A timer was superimposed to the video-recording in order to allow the precise coding of events (the first set at 00 for the hour, the second at 00 for the minutes, the third for the seconds and the last for the number of frames; there were 25 frames per second). The multimedia video editing software, Final Cut Pro, was employed to edit and synchronise the recordings. The viewing and coding of the recording was done using a Panasonic NV HS960 super drive multi-intelligent control IIVHS player, a JVC 14-inch television and an editing controller, ww-EC500E.

Materials

The computer programmes 'Speaking for Myself', 'Sentence Master' and 'Wellington Square' were chosen for the study based on the guidelines for selecting appropriate educational computer programmes (Tuedor, 2006). The latter was subsequently eliminated due to the fact that the participants may have been exposed to it previously (as it was a programme used in the school) hence its use would not have provided a reliable picture of the success of the programme in teaching new words.

The 'Speaking for Myself' (FM) programme was designed using Director multimedia software. The programme employed a combination of animation, pictures, images, sound, speech and video clips; it targets children between the ages of 2–9 years with special educational needs. The educational computer programme 'Sentence Master' (SM) Version 2.0 was designed by a developmental psychologist and specialist in reading and oral language (Blank, 1996). The programme utilises animation, sound, images and speech, and is repetitive, placing emphasis on non-content words. This programme is targeted at children with special needs between the ages of 2–9 years or children having difficulties learning to read.

The main differences between the two programmes are indicated in the methods they employed, the way the programmes were structured, their content and the teaching approach/strategy they employed. The SM programme taught new words using four methods: word introduction, word recognition, sequential recognition and spelling. The FM programme taught new words using talking stories, photographs of the object taught, flash cards of everyday words, nursery rhymes and video recording of a person using sign language to teach the words. Whilst the SM programme used words, images and animation, the FM employed words and photographs of real objects. The response time in the SM can be set from minutes to a very large value, but this tool was not employed in the FM programme. The SM program utilised prompts in its teaching strategy (this involves using audio commands to instruct the child to select the word being taught; for example 'select bus' or 'press a key to continue') whilst no prompt or repetition was present in the FM computer programme.

Observation Coding Scheme

Three types of events were selected for measuring the interactive sessions to determine the children's attention, motivation/responsiveness and engagement (dependent measures in brackets):

(1) The children's sustained attention was measured by recording the looking time where a child would continuously look at the computer screen (as proportion of session duration).
(2) Motivation/responsiveness was recorded in terms of touching the computer screen either spontaneously produced or produced in response to external prompts by the computer programme, or physical and verbal prompts by the facilitator (frequency and rate).
(3) Engagement was recorded in terms of episodes of boredom and stress showed by the children including hand movement and flapping, vocalisation and facial/postural displays of negative affect (frequency of events and duration of time spent in negative behaviour divided by the total time session x 100).

Inter-observer reliability was measured on a randomly selected 20% of the video data analysed in this study. Simple agreement between two coders was computed for all dependent measures. The inter-observer agreement achieved was 93% on average. This indicated a high level of consistency between the two observers hence confirming reliability of the coding scheme.

Ethical Considerations

Comprehensive analyses of ethical issues were addressed in the planning and implementation of this study. The study took into account the sensitivity of the research topic and the vulnerability of the research participants as in Greig and Taylor (1999). The research was carried out in close consultation with the Ethics Committee of the School of Computer Science, Middlesex University, to continually address the ethical issues related to this study.

Informed consent and confidentiality were upheld in this study. Since the study required access to children, the consent of both the parents and the school was obtained. The researcher stopped or cancelled the test if the participant displayed any signs of unwillingness to take part in any of the activities of higher intensity than what normally occurring in their usual learning sessions.

Results

The results of the study indicated some gains in the acquisition of new words when comparing pre-/post-tests (See Table 1) confirming that computer programmes promote the acquisition of new words (research question A).

The performance of children with ASD appeared superior with programme SM than FM. However, two children missed either the pre- or post-test session for the programme FM, making the comparison across software possible only for three cases.

This result is encouraging in terms of finding ways to quantify and compare gains after exposure to educational computer programmes with different characteristics; however larger samples would be needed to draw conclusions. One of the main aims of this study was to evaluate the quality of the interaction instigated by the software and investigate whether they met the needs of the target audience (research question B). In order to shed more light

Table 1. Pre- and post-test scores for the ASD cases (N words) with software FM and SM.

Software FM						Software SM					
Participants ID	Pre- intervention score		Post- intervention score		Gains	Participants ID	Pre-intervention score		Post- intervention score		Gains
	Words tested	Words known	Words tested	Words known			Words tested	Words known	Words tested	Words known	
ASD 1	3	0	3	0	0	ASD 1	2	0	2	2	2
ASD 2	3	0	3	0	0	ASD 2	3	0	3	2	2
ASD 3	3	0	3	2	2	ASD 3	2	0	2	2	2
ASD 4	(M)	(M)	3	2	0	ASD 4	(M)	(M)	(M)	(M)	(M)
ASD 5	3	0	(M)	(M)	0	ASD 5	3	0	0	0	0

Notes: ASD – Autistic Spectrum Disorder. Missing data: ASD 4 in the FM program had no pre-test scores and was not available for testing in SM. ASD 5 in the same program had no post-test scores. Absence is denoted by M (missing).

on the actual child–computer interaction and the learning experience, the video-recordings of the participants interacting with the software were analysed. The results for each area of behaviour studied (target codes) will be presented first for children with ASD, followed by neurotypical children.

Attention/Looking Time

The percentage of time for which each child with ASD looked at the computer screen for both computer programme is shown in Figure 1(a) and (b). For the FM software, two children scored above 50% and one child scored below 30%. For the SM software, three children scored above 50% and one child scored below 30%. For children ASD1 and ASD2, the results indicated that child ASD1 displayed more sustained attention with the SM software (81% confirming hypothesis 1) than the FM software (29%), while the difference in attention to the two software programmes was marginal for child ASD2 (< 10% difference).

Similar comparisons among the TD children showed that this measure (attention/looking time) appeared sensitive to individual differences in preferences (see Figure 2(a) and (b)), with child ASD2 preferring FM, while children TD1 and TD5 preferring SM, and children TD3 and TD4 showing no preference. Finally, a comparison between the ASD and TD cases revealed, on average, higher percentages of looking time for the TD children. However, both groups showed a good level of interest, as demonstrated by the relatively high percentage of time spent looking at the screen during treatment with either types of software.

Motivation/Responsiveness

The results shown in Figure 3(a) and (b) illustrate the frequency of children's touches to the computer screen, which were either spontaneous or following different types of prompts (hypothesis 2). Although all children produced a varying amount of spontaneous touching behaviour, they also showed some individual differences in the kind of prompt they were more likely to respond to by touching the screen. For example, child ASD1 engaged in more touching with SM than FM, whilst child ASD2 recorded more touching in response to the prompts with the FM software. The highest amount of touching was recorded for child ASD3

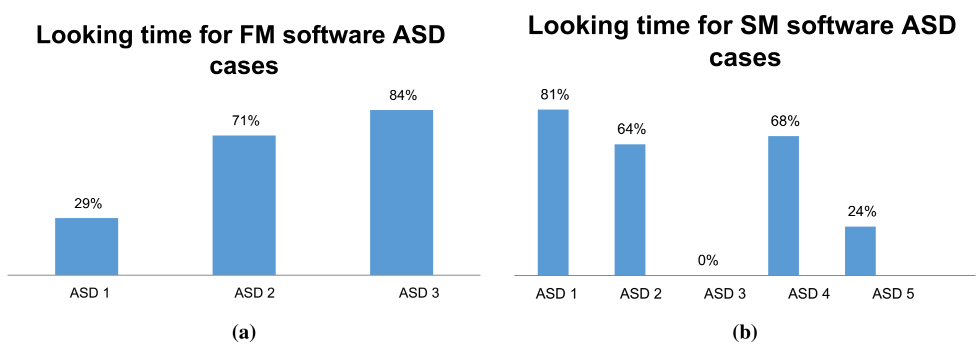

Figure 1. (a) Percentage on-screen attention behaviour deployed with FM software (ASD cases). (b) Percentage on-screen attention behaviour deployed with SM software (ASD cases).
Notes: ASD – Autistic Spectrum Disorder. Children ASD4 and ASD5 were absent from the FM session, and child ASD3 was absent from the SM session.

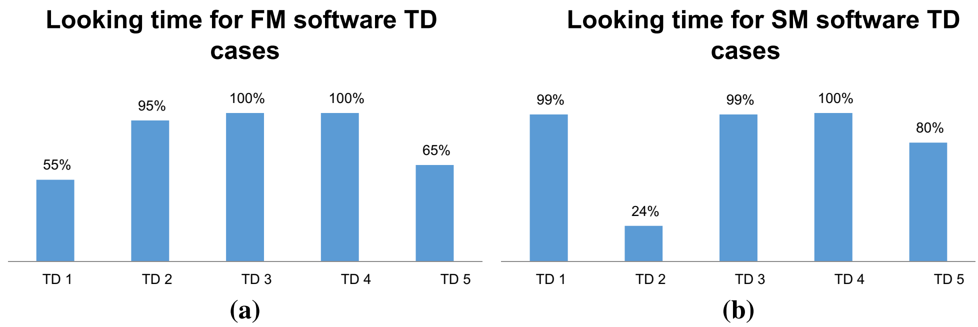

Figure 2. (a) Percentage on-screen attention behaviour deployed with FM software (TD cases). (b) Percentage on-screen attention behaviour deployed with SM software (TD cases).
Note: TD – typically developing children.

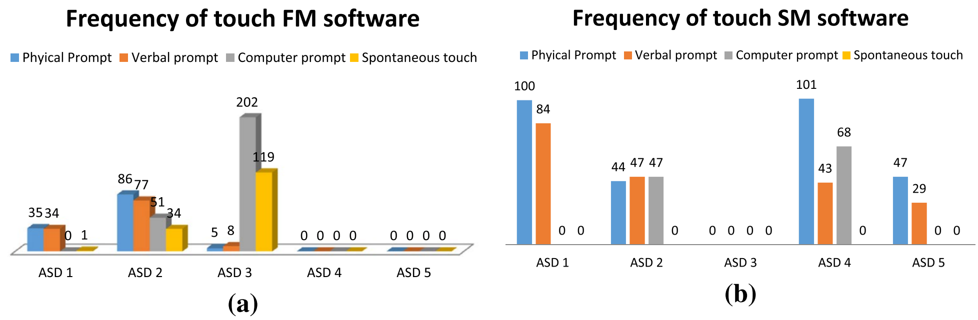

Figure 3. (a) Frequency of touch behaviour following different types of prompt for the FM software (ASD cases). (b) Frequency of touch behaviour following different types of prompt for the SM software (ASD cases).
Notes: ASD – Autistic Spectrum Disorder Children ASD4 and ASD5 were absent from the FM session and ASD3 from the SM session.

with the FM software. Overall, there appeared to be a greater amount of touching behaviours with the FM than the SM software, although data were not available for children ASD 4 and ASD 5 on the SM session.

Engagement (Stress/Boredom)

All events related with loss of engagement (respectively, hand movements or flapping, vocal and facial negative affect) were analysed in function of their duration and frequency (number of episodes of each type of behaviour) (Figure 4(a) and (b)). Figure 5(a) and (b) report the results as percentage of the duration of a session during which stress/boredom were displayed (hypothesis 3).

The children with ASD showed higher proportional duration of boredom/stress episodes when using the SM than the FM software. A direct comparison was only possible for children ASD1 and ASD2 (who used both computer programmes). Child ASD3 in the FM software had no recorded boredom or stress, which indicates that he was the more engaged whilst using

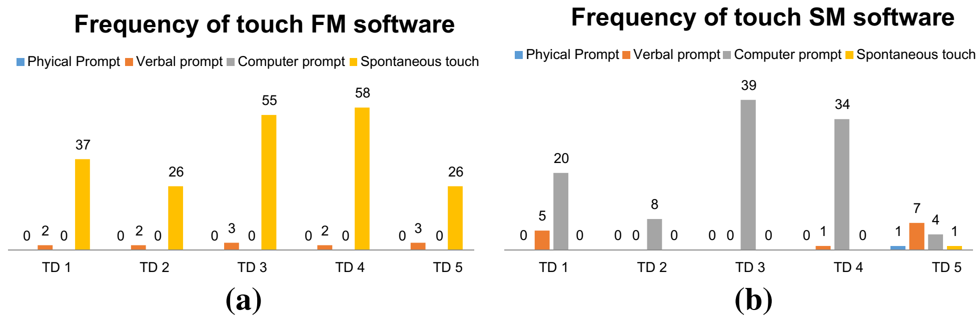

Figure 4. (a) Frequency of touch behaviour following different types of prompt for the FM software (TD cases). (b) Frequency of touch behaviour following different types of prompt for the SM software (TD cases).
Note: TD – typically developing children.

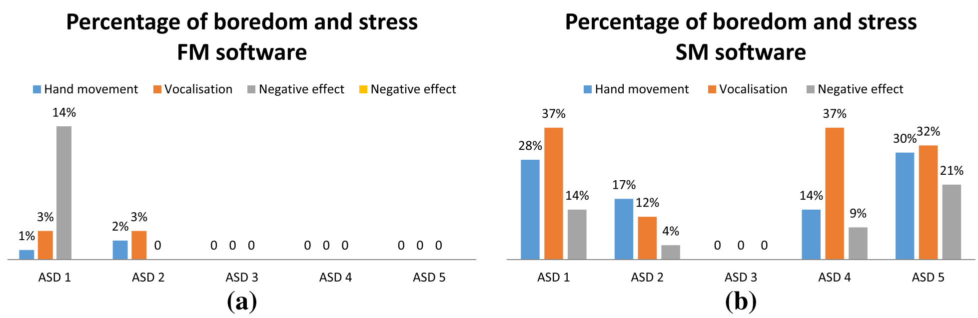

Figure 5. (a) Duration of disengagement as percentage of session recording boredom and stress events (ASD cases) with FM software. (b) Duration of disengagement as percentage of session recording boredom and stress events (ASD cases) with SM software.
Note: Children ASD4 and ASD5 were absent from the FM session and ASD3 from the SM session.

this software. However, consistently with the first two cases above, participants ASD4 and ASD5 displayed frequent episodes of boredom/stress when using software SM.

In contrast, neurotypical children recorded overall very low levels of boredom/stress (<10% in all categories), suggesting that both FM and SM programmes can engage TD children.

Discussion

The pre-/post-test results of this study suggested that the children with ASD tended to learn more words with the SM computer programme than the FM, consistently with Moore and Calvert's (2000) investigation with 14 children leading them to claim that a computer programme can create an interesting, stimulating environment for children with ASD, as well as confirming hypothesis/research question A.

The study was successful as a proof of concept aiming to demonstrate that empirical analyses of the behaviour of ASD users while interacting with software are providing important cues on both the effectiveness of the software for learning and its enjoyment (hence long-term potential) for children with ASD (hypothesis 1 and 2/research question B). Future research will need to isolate specific features of educational software, analyse them in function of the cognitive profile of a given population and test them empirically with users in a controlled manner.

An overall group comparison on the observation results (attention, motivation and engagement with the SM and FM programmes) showed that both ASD and TD cases tended to record higher levels of attention when using the FM software, than with SM; children with ASD recorded a higher degree of touching of the screen in response to a prompt than the TD children, as well as displaying more episodes of boredom/stress when using the SM than the FM software.

More specifically**,** when comparing the two groups of cases, TD children showed higher attention levels than did the children with ASD, consistently with research highlighting attention difficulties associated with ASD (Frith, 1989; Happe, 1999; Wing, 1996). Both groups tended to be more attentive in the FM than the SM program, possibly as a result of the interactivity and attention grabbing features provided by this programme. However, an interesting aspect emerged in relationship with this measure is a certain level of individual differences, with different children paying attention more to one program rather than the other.

When considering motivation/responsiveness, higher levels of touching related with physical and verbal prompting were found with the SM than the FM software, indicating that verbal and physical prompting is crucial for motivating children with ASD to use the computer programme. This appears consistent with the findings of Tjus et al. (1998), who found that children with ASD and various cognitive disabilities benefitted from a strategy that combined a motivating multimedia programme and positive interaction with the teacher. This result is also compatible with the view that children with ASD present unstable motivation levels (Frith, 1989) and appear to benefit from the administration of rewards (as in the Applied Behavioural Analysis or ABA: Simpson, 2001). Thus, the use of prompts may be associated with the greater number of words learnt by children with ASD when using the SM software in the pre-/post-test comparison. This likewise suggests that computer prompts in an educational programme could alleviate attention problems when children with ASD utilise an educational programme in learning new words (confirming hypothesis/research question B).

Although TD children produced more instances of spontaneous touching with the FM programme and more touches with computer prompts in the SM program, overall they did not need as many prompts as children with ASD, likely to be due to TD children succeeding to follow the software autonomously.

Also for this measure individual differences were observed. Therefore, although the results support the usefulness of prompts for children with ASD, further research is needed in order to determine which type of prompt is more effective for children with ASD. This is suggested also by the results concerning the third measure (engagement), as episodes of stress/boredom were significantly more present when using the SM than the FM software in children with ASD, and were almost non-existent in TD children with either types of software.

Taken together, the results for motivation and engagement elucidate a very important issue in finding the appropriate balance between repetitions (which may lead to disengagement and frustration) on one hand and repeated rewards on the other hand (which appear a useful support device for children with ASD). As a consequence, trying to determine the threshold or limit of the level of repetition that should be employed in the computer programme is a challenge. Prior knowledge of a child may help to determine this, hence it would be beneficial to provide features within the computer programme, whereby the teachers and parents of a child with ASD can adapt the programme to a level of repetition that is considered suitable, thus supporting a child's best performance.

The lack of structure appeared to create some anxiety in the children with ASD, which in turn lead to episodes of boredom/stress (in line with hypothesis 3) particularly in the FM programme that has no obvious beginning or end. The children with ASD worked through the computer program using the navigation arrows (hurrying through the pages, using the navigation button as if they were searching for the end of the session). The fact that there was no obvious end to or exit from the FM session may also be the factor that made some of the TD children asks for the session to end prematurely. These findings are consistent with the claims by Frith (1989) and Wing (1996) that structure is of particular importance to children with ASD. Thus, this factor may be another explanation of why children with ASD learned more words in the pre/post-test comparison with the more clearly structured SM than less structured FM software. This is compatible with Autism Speak (2016) who reported benefits of structure and repetition in the learning and teaching of children with special needs. However, in order to evaluate the weight of different factors on children's learning, future research should test separately the effects of repetition/rewards and structure on learning with educational software in children with ASD. These two aspects are confounded in the software used in the present study, as SM is both more structured and containing more repetitions and rewards than FM.

In summary, this study contributes observational behavioural data on attention, motivation and engagement to the view that attention in children with ASD can be supported by interactivity in computer software, as suggested by the National Autistic Society literature (2016a) but an understanding of the learning style of children with ASD is needed in order to design software effective in supporting specifically these children's learning (Moore & Calvert, 2000).

From the findings discussed above a framework to facilitate the design of effective educational programmes for children with ASD was developed, which is presented in the next section.

Framework for the Design of Literacy Educational Software for Children with ASD

The findings discussed above revealed issues that need to be addressed, concerning the design in both computer programme employed in this study. The information obtained from this study and other research in related fields (such as mental health, cognitive disabilities, Human Computer Interaction or HCI, cognitive psychology and social science) needs to inform Child Computer Interaction (CCI) research and design, and serves as the basis for the theoretical framework shown in Figure 6.

The diagram in Figure 6 details the essential components needed in the design of effective educational computer programmes for children with ASD. The framework proposed (Tuedor, 2009) consists of the following components:

DG1 – 'Learning Theories for ASD'

This part of the framework examines the various learning theories derived by theoretical models of ASD with a view to incorporating these theories in the design of educational

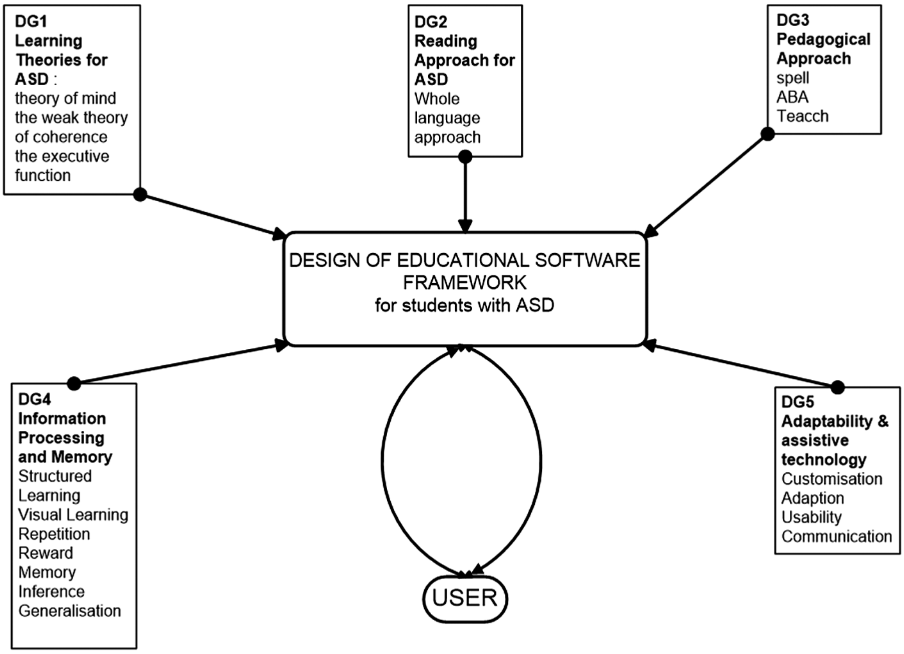

Figure 6. Interdisciplinary design framework for literacy educational software, for children with ASD.

software. Examples of these theories of ASD could be the theory of mind model (Baron-Cohen et al., 1985), the weak central coherence theory or the executive function theory (Happe, 1999), all of which identify specific ASD characteristics emphasising different cognitive, emotional and linguistic aspects of development.

DG2 – 'Reading Approach for ASD'

This component aims to evaluate different models of learning to read, for instance the whole language approach *vs.* phonics (differently from the latter, the former recommends teaching the whole word, for example the word 'dog' rather than the phonemes /d/ /o/ /g/ making the word). Such models of reading development and education (see for example Goswami, 2006) must be considered in relationship to DG1 and DG4 and specifically studied in the context of ASD.

DG3 – 'Educational/Pedagogical Approach for ASD'

This part of the framework is concerned with identifying the most appropriate teaching methods for ASD. It examines existing teaching approach for ASD such as the Structure Positive Empathy (SPELL – The National Autistic Society, 2016b) and the Low Arousal and Applied Behaviour Analysis (ABA – Autism Speak. Applied Behaviour Analysis (ABA), 2016) approaches. It also proposes designing the educational literacy software considering a combination of 'ASD friendly' design techniques such as, the Tutorial Drill and Practice (TDP), Reading Programme or Educational Reading Program (RP/ERP) and Educational Games (EG), in a multimedia environment (Heimann et al., 1995).

DG4 – 'Information Processing and Memory in ASD'

This component looks to address specific information processing strengths and weaknesses in children with ASD, for example weaknesses in attention to whole social aspects and strengths in auditory processing (Mottron, Dawson, Soulières, Hubert, & Burack, 2006) in the design of educational literacy/reading software for ASD.

DG5 – 'Adaptability and Assistive Technology'

This aspect of the framework examines additional devices the children with ASD may need to utilise the software effectively. It stipulates using assistive technology where necessary, for example using 'large key keyboard', 'accessible mouse' and touch screen. It also advocates for incorporating adaptive and adaptable system approach in the software design. This method will enable the child with ASD or educationalist (for example a teacher or parent) to customise the software to suit the child's specific needs (adaptable system). On the other hand the system can automatically adapt itself (based on the child's past interaction history) to the child's needs and preferences.

The proposed framework addresses the gap identified in the design and implementation of educational computer programmes employed to facilitate the teaching of early reading with children with ASD, including those at the lower-functioning end on the spectrum, a neglected group. The solution to this gap, it is anticipated, will combine aspects of the attributes and learning styles of autism, effective teaching approaches and suitable reading methods for children with autism, in addition to implementing adaptable and adaptive system design model. In other words, only a genuinely interdisciplinary approach complemented by rigorous testing will be able to address the challenge involved in the task at issue. Such future research will develop new theoretical models for designing educational computer programmes not only for children with ASD, but also with other learning disabilities.

Conclusion

In order to employ computing technologies to support learning in children with ASD, it is essential to understand how to present information to them and how to make an impact on children and adults with autism who have some abilities and disabilities which are a direct result of the syndrome (Siegel, 2003). Although more challenging, this is even more urgently needed for low-functioning individuals, who represent ≥70% of the ASD population.

Some of the abilities of children with autism have to be channelled in order to compensate for some of the learning difficulties associated with this disorder. It is therefore necessary, when designing programmes for children with autism, to consider their cognitive profiles hence requirements and preferences, in order to provide an environment that suits their learning style. This would minimise the impact of the disability (when the child comes to learn using computer technology) while capitalising on their strengths. It is crucial to note that, as autism is a spectrum disorder, this implies that it affects each individual differently. Hence, at each stage of development, a child may experience different learning strengths and learning disabilities (Siegel, 2003). It is therefore important to understand the various ways in which children with ASD could be taught to learn using computer technology and to apply strategies at the appropriate developmental level of the child. Hence, a developmental perspective taking into account possibly different 'developmental trajectories approach' (Thomas et al., 2009) is recommended when designing future quantitative studies.

This proposed framework may be considered a response to Powell and Jordan's (1997) call for a cognitive perspective on the way in which children with ASD think and learn. The authors call for recognition at a psychological and educational level of how the world is viewed from the perspective of an individual with autism, and of the structure of how these children are taught in order to reflect their needs. As a result of the present study, however, we propose to reformulate this call as an inter-disciplinary task. We deem the proposed framework as promising and linked with the topical area of technologies in medicine and education, although the proposed guidelines need further refinement and testing on a larger scale. It is anticipated that the proposed framework will assist in the development of research in this domain, and the application of these guidelines to educational computer programme will be extended to other aspects of learning as well as in other intellectual disabilities. It is also anticipated that the suggested set of guiding principles will provide a first stop for researchers and designers of educational computer programmes for children with ASD seeking guidelines to facilitate the design of effective learning-support programmes for this population.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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