An augmented toy and social interaction in children with autism

William Farr* and Nicola Yuill

School of Psychology,
University of Sussex,
Pevensey Building,
Falmer, Brighton BN1 9QH, UK
E-mail: w.j.farr@sussex.ac.uk
E-mail: nicolay@sussex.ac.uk
*Corresponding author

Steve Hinske

Institute for Pervasive Computing,
ETH Zurich,
Main building,
Rämistrasse 101,
Zurich 8092, Switzerland
E-mail: stevehinske@gmx.net

Abstract: An Augmented Knight's Castle (AKC) play set was adapted so that children with autism can configure programmable elements. This is compared with a non-configurable AKC. When the system is configurable, and when it is switched on, less solitary play and more cooperative play occur. Digital toys and their configurability are key factors in design for children with autism, allowing greater individual control and more socially oriented behaviour. We suggest that tangibles provide a safety net for encouraging social interaction as they allow for a broad range of interaction styles.

Keywords: tangibles; configuration; autism; object interaction; social interaction; direct manipulation.

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Biographical notes: William Farr trained as a Primary School Teacher at the University at Sussex and worked in schools for 12 years. During that time, he taught in Tottori Prefecture in Japan, and completed an MA in Education, focusing on autism and computing. After finishing the National Professional Qualification for Headship (NPQH) and working as a Deputy Head Teacher, he was offered an EPSRC sponsored DPhil. He is currently a third year DPhil student in Psychology, focusing on autism and tangibles and he is also an Associate Tutor in Education and Psychology for MA and undergraduate programmes.

Nicola Yuill, after working on the theory of mind, researched children's language comprehension, leading to work on understanding language ambiguity in riddles and mothers' conversations with children; this prompted her interest in technology's role in how children learn through conversation – culminating in setting up the children and technology lab (ChatLab). In the lab, she coordinates and runs research into how technology can be used to understand and support children working and playing together, at school and at home, in typical and atypical development, with peers, with parents and with teachers.

Steve Hinske studied Wirtschaftsinformatik (Business Administration and Computer Science) at TU Darmstadt, Germany and received his diploma in 2005. After this, he was a Research Assistant and a PhD student at ETH Zurich, Switzerland and received the doctoral degree DrSc in 2009. He has worked with the Distributed Systems Group and the Mobile and Ubiquitous Computing Lab team. His research focuses on the digital augmentation of traditional play environments. During his studies, he has spent time in the USA, the UK, Japan, Singapore and Australia, either as an intern or as a visiting researcher.

1 Introduction

Digital technology for individuals with special needs plays an important supporting role (e.g. Baron-Cohen, 1997; Baron-Cohen et al., 2007). For children with autism technology can be a 'compensatory mechanism' a psychological tool that can 'transform…natural abilities into higher metal functions…' (Vygotsky and Luria, 1994, p.344). As children with autism experience a divergence between their natural and social developmental paths, equipment, tools and objects highlight social and interaction use and offer ways of mediating and improving development (Kozulin and Gindis, 2007). Technology offers compensatory mechanisms that can support children in their abstract reasoning, logical memory, voluntary attention and goal-directed behaviour (Kozulin and Gindis, 2007). Interactive technologies, in particular, can play a further role in the development of social skills by socially mediating interaction and aiding peer-to-peer relations and collaboration (Marti et al., 2009).

Digital technology often appeals to individuals with autism, and can help redress some social deficits (e.g. see Baron-Cohen et al., 2007). Computers allow children with autism a chance to encounter tools and symbols that can support social interactions, help direct behaviour and help motivation within activities. One of the reasons why this may be the case is that computers contrast with human behaviour as they do not react to the odd behaviour typically found in autism (Jordan and Powell, 1995). The stress and unpredictability caused by social interaction is largely removed during computer interaction (Murray, 1997). Tangible user interfaces (TUIs), and in particular augmented toys (ATs) – which are a branch of computer science – may be beneficial, as manipulation presents the individual with an opportunity to interact directly with data.

Here, we investigate the hypothesis that a digitally augmented play set that can be configured by children with autism will increase social interaction. We also look at the system when digital elements are switched off to see if differences in play are due to augmentation. ATs allow children to trigger and configure digital content (Hinske et al., 2009). The AT in this current study, allows toy figures to be played with that speak, and also allows these figures to be programmed with children's own voices. The Augmented Knight's Castle (AKC) play set (Lampe and Hinske, 2007) was used to see whether configuration of the AKC increased children's social engagement when children with autism controlled feedback and could programme where, when and what radio frequency identification (RFID) figures said. If the configurable element is important, there should also be a difference between the augmentation and non-augmentation. Children's play should be enhanced by augmentation.

In the following sections, we look at the field of TUIs, and object interaction as an impairment in autism. This dual look at TUIs from the field of human–computer interaction and psychology sets up our reasoning behind looking at an AT as means of promoting social interaction in children with autism. We then turn to a description of the system used, our method of investigation, present the results and discuss our findings.

2 Augmenting toys and tangible user interfaces

TUIs are objects with embedded digital technology (Ishii and Ullmer, 1997). ATs are a subset of TUIs and are toys that are enhanced with digital technology (e.g. see Hinske et al., 2008, 2009). TUIs are in graspable form, and allow users the opportunity to directly manipulate data input through objects (Ishii and Ullmer, 1997). The possibility of manipulating objects through digital and physical actions introduces a novel element into user action (Ullmer and Ishii, 2001). A variety of feedback mechanisms can occur, such as visual engagement, kinaesthetic interaction, or audio and haptic feedback (Lampe and Hinske, 2007; Hinske et al., 2008). TUIs allow for a variety of 'mappings' between physical and digital space (e.g. Shaer et al., 2004); in this case the impaired ability to predict change in human behaviour in autism relates directly to behavioural mapping, or the cause and effect of a tangible (Antle, 2007; von Hofsten et al., 2009).

A tangible interface for children with autism may also promote co-located cooperative work as shown with work, using Topobo (see Farr et al., 2010; Ullmer and Ishii, 2001). TUIs encourage reflection and discussion about the objects as they are used (Hornecker and Buur, 2006). Interaction with tangibles allows other people to be identified as intentional agents, especially with the addition of goals like configuration (Passerino and Santarosa, 2008). Digital and physical effects in TUIs can often be recorded, and this record of change has been shown to help individuals focus on activities (Hornecker and Buur, 2006). For TUI used here – described below – programming is by demonstration, and control of input/output is user controlled (Edge and Blackwell, 2006). This is often referred to as 'end-user' programming and is a system method, where building, constructing and playback of programmed elements occur via the construction or interaction with an object. The user programmes the interface during interaction. Users are given the '[a]bility to redefine what actions are used at what time' (Edge and Blackwell, 2006). This extension of being able to manipulate TUIs means the manipulation itself directly becomes the programming. This system factor enables the user to control when and how feedback of programmed aspects occurs.

Multiple entry points are, therefore, present in an activity with a TUI, as they are made by physical manipulation, manipulation of data, observation of digital effects, listening, talking and playback of digital features. This clear functionality allows children to observe cause and effect, which can be both motivating and help reinforce attention to objects through tangible interaction (Fernaeus and Tholander, 2006). Further, meaningful manipulation and control of digital information enable multiple and subjective interpretation to occur as TUIs become shareable resources for action (Fernaeus et al., 2008). These multiple entry points, both data and socially oriented could be beneficial for children with autism (Antle, 2007; Marshall et al., 2003).

3 Object interaction and autism

Autistic children are additionally affected not only by social difficulties, but also are impaired in their understanding of object interaction (Jordan and Powell, 1995; Tager-Flusberg and Anderson, 1991; Williams et al., 1999). Therefore, predictable cause and effect in tangible systems has the potential to support person-to-object-to-person interaction.

Most object use for children occurs during play. As play is an important indicator for the quality of children's lives, tangibles and ATs can be used to logically extend object function, appearance and can provide a high-quality experience, whilst minimising confusion with predictable digital effects (Antle, 2007; Marti et al., 2009; Tager-Flusberg and Anderson, 1991). Objects can provide fixed or flexible cues, and those that require little cognitive negotiation become easier to use (Norman, 1988). Objects when created in an appropriate manner become tools, moving from being objects which are simply present to useful objects, so much so that they almost 'disappear' as they become unconsciously used, thus moving the object beyond the realm of simple tool to psychological tool (Heidegger, 1962).

Toys are play objects that are familiar, and with the addition of digital technology provide quality materials for play. For example, Topobo (Raffle et al., 2004) when linked together form objects that look like animals and insects, and when programmed can playback movement. The digital playback in Topobo extends logically from its functional use. If a creature is constructed, then programming enables the creature to move. When Topobo is used in a structured play setting, children with autism are significantly more likely to play with others in parallel, and less likely to play in a solitary manner (Farr et al., 2010).

Children with autism experience difficulties in understanding how to use objects flexibly in social situations (Williams et al., 1999). Object use is often a social process which children with autism find difficult (Williams et al., 1999). Functional or sensori-motor use of an object is easier for a child with autism to understand than that of symbolic use (Rowland and Schweigert, 2009). Symbolic use of objects occurs when children play and develop imaginary situations (Leontyev, 1981). Playing with objects is repetitive and often inflexible with low levels of exploratory behaviour (Jordan and Powell, 1995). Proximal senses like touch with the hand or mouth are favoured to gather information as opposed to auditory or visual means (Williams, 2003). Without a clear understanding of the functional use of an object, features and aspects often become fixated upon (von Hofsten et al., 2009).

For children with autism, frequency and quality of object play depends on the type of object and the structure of the situation (Tiegerman and Primavera, 1981; Williams, 2003). Pairing children with severe autism with an adult playing with an object in parallel increases interaction during positive imitation (Tiegerman and Primavera, 1981). Greater frequency and duration of play also occur, depending on the play material and structure employed (Tiegerman and Primavera, 1981). If object interaction changes with situation and context, especially if objects are similar and are placed within an environment that promotes play in parallel, tangible interaction should promote social interaction in children with autism.

To summarise this section:

- an ability to predict the flexible way in which objects can be used is impaired in autism
- the structure, presentation and type of object interaction can positively influence interaction in children with autism by reducing solitary behaviour and encouraging parallel play
- tangible systems give feedback that supports an understanding of cause and effect in autism
- technology can provide compensatory mechanisms for children with autism, whilst minimising confusion during social interaction.

4 The AKC

The AKC is an AT environment, consisting of three base units that are wirelessly connected to a system server. An earlier version consisted of one centralised play set (Lampe and Hinske, 2007). The base units are equipped with RFID readers and antennas, which allow location and identification of individual Playmobil figures. The figures have RFID tags attached to the base of the feet, inside the head and into the back section of the figure. As the tags used in this experiment were very small (i.e. between 0.9 and 1.5 cm in diameter), the tags could be almost invisibly integrated.

When figures are placed into one of three base units (a castle, a dragon tower and a magic pond play area – see Figure 1), antennas detect RFID tags and readers then relay the tag specific information of that figure back to the laptop. Pre-recorded sounds are then played. A read cycle, checking for figures in range occur almost in real time (Figure 2).

Investigations with typically developing children have already been extensively conducted with the AKC (Hinske, 2009; Hinske et al., 2009) and found positive results for the AKC when compared to a Knights Castle play set in children's play when content can be chosen. The importance of controlling content for children is well documented (Papert, 1976, 1980), but is especially important for children with autism as a powerful method for motivation and learning (Keay-Bright, 2008; Murray, 1997; Panyan, 1984). A variety of iterations were attempted during the creation of the AKC (Hinske, 2009) but allowing users with autism the chance to make content offers exiting potential for tangibles user interfaces.

Figure 1 The Augmented Knight's Castle play set (see online version for colours)

Figure 2 The Augmented Knights Castle, showing dragon tower, castle and magic pool (see online version for colours)

5 Method

5.1 Participants

A sample of children (*N* = 12) with a medical diagnosis of autism (mean age = 11.2) from a special needs school for moderate learning difficulties, were used. Children participated in groups of three. Three groups were made of boys (two groups aged 12–13, and one group aged 9–10) and one group of year five girls (aged 9–10). Consent was obtained from children, parents and the school.

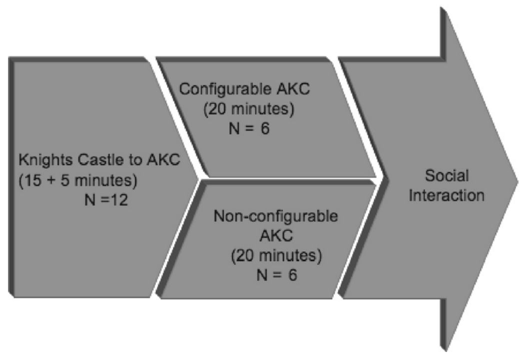
The child's severity of autism was screened through the use of the Childhood Autism Rating Scale (CARS) (Schopler et al., 1980). The CARS rating scale is made up of 15 questions, covering questions from children's social skills to object interaction. Scores are compiled through observation and discussion. The child's teacher made the judgement on CARS score. The mean score was 31.04 (SD = 8.87), listed on the scale as moderate autism, but with variance in scores from moderate to severe autism.

5.2 Design

A two group ($N = 12$), two condition (configuration, non-configuration), between subjects design was used (see Figure 3). Two groups were presented with the configuration condition in session two, and two groups were at the same time presented with the AKC in non-configurable format. Children in the configuration condition could place figures in a 'magic box' that contained an RFID reader. The reader scanned figures, and the laptop server recognised each figure, using RFID tags. The option to speak into a microphone and programme each figure's speech was available. The researcher programmed the location, where a character would speak, but children eventually learnt this (Figure 4).

Figure 3 AKC internal RFID technology, antennae (right hand side), multiplexers and surround sound inside main housing (see online version for colours)

Figure 4 Experimental method



5.3 Stimuli and apparatus

Children's play sessions were recorded using a digital video camera. Sessions took play in a room 4 m^2 normally reserved for computer work. Children were given 10 Playmobil figures in the configuration condition and 20 Playmobil figures in the non-configuration condition. This was to offset the learning time required to configure characters otherwise children may take more time simply learning how to configure. A timer was on display for the children to know how much time was left in their play session.

5.4 Procedure

Play sessions were conducted over one week. One day elapsed between each play session. Play sessions were 20 min in length. Standardised instructions were given across the two conditions. These were:

Session 1 Knight's Castle (KC) to AKC session. This is a Playmobil set. You can play with it how you like. There is no right or wrong way of playing with the set; it is up to you how you play with it. After 15 min the AKC will be switched on: The set say things. Look at this character. If I put him here, this happens (demonstrate placing a character in the AKC).

Session 2 Non-configurable AKC condition: You have 20 min to play with the set again. Remember, if I put a figure here, then this happens (demonstrate figure talking by placing in the AKC). You will have 20 min again to play with the AKC.

Configurable AKC condition: You have 20 min to play with the set again. Remember, if I put a figure here, then this happens (demonstrate figure talking by placing in the AKC). The magic box will let you make characters say different things. I can make it do this (demonstrate by recording a sound and placing in the AKC set). You will have 20 min again to play with the AKC.

5.5 Coding

Videotapes were coded using Mangold Interact™ software, using a coding scheme shown in Table 1 (modified from Robinson et al., 2003; Parten, 1932). Modifications were made to accommodate children with autism with the inclusion of a code for repetitive behaviour. Children with autism often get caught in a cycle of repeated action that is unrelated to the functional use of an object (e.g. see Tiegerman and Primavera, 1981). This coding scheme provides a descriptive account of play suitable for both typical and autistic groups of children in clear play patterns. This coding scheme has been used before (Farr et al., 2010) but was modified to include recent developments and clarification on particular codes like solitary and parallel behaviour (see Holmes and Procaccino, 2009; Rowland and Schweigert, 2009). Inter-rater reliability yielded a κ of 0.73 on a coding sample of 30% of all video.

Table 1 Coding method

Code	*Definition*
Disengaged	Child is not attending to the task, object or other individuals within the group
Onlooker	The child is watching what other individuals within the group are doing but does not actively take part
Solitary sensori-motor and constructive play	The child is taking part in the task, or constructing an object but is working alone rather than with others. The child acts on an object alone
Parallel sensori-motor and aware play	Child chooses to work alongside another participant but does not influence or modify other person's work. Plays beside rather than with. This may include imitation. The child acts on an object and remains aware of what other individuals are doing in relation to an object
Associative play	Borrowing and loaning of play material – no division of labour and no organisation individual acts as he wishes, group play. These actions are usually swift and may include passing, giving, exchanging of objects
Co-operative-social play	Child works with another person by turn-taking or discussing play outcomes. Tasks are distributed together, e.g. hands on something at same time or discussing outcome together
Repetitive play	Repetitive, ritualised or odd behaviour that has no impact on other children; cycle of action with no functional relevance to the object used

6 Quantitative results

Quantitative data is now presented on video-coded data. A discussion of methods used for analysis, followed by data comparing children's play states and sequential play patterns for the AKC compared to the Knights Castle is discussed. This is followed by data comparing the configurable with the non-configurable AKC. Finally, additional data are presented on RFID figure usage.

6.1 Autistic children's play with the AKC

All individual data from analysis were broken down according to play state frequency and duration. All reported data are from the 20-min play session, and are raw transitional data for one type of behaviour to another. All interaction figures are for children grouped in threes, each diagram consisting of total scores for four groups (Figures 5 and 6) and two groups (Figures 7 and 8). All children were presented first with the KC switched off, before the AKC was switched on. In the second session, children were then allocated to either the configurable or non-configurable condition. Total amounts of raw play by type are not presented, as these do not show the interaction patterns that the figures presented below show.

We studied sequential patterns of play in each group, using contingency analysis. Contingency analysis provides the raw frequency of one play state following another. To assess likelihood of one state occurring after another, raw data were converted into a D'Mello score (D'Mello et al., 2007). This has been used before with tangibles and children with autism (see Farr et al., 2010). Here, an augmented environment broadens the scope of this earlier work. The overall effect of using the D'Mello score is to highlight how children with autism play with tangibles by isolating play patterns. The D'Mello statistic, similar to Cohen's *K*, shows the probability that movement from one state to another given the probability of a previous state will occur when compared to a baseline frequency of a particular play state (Rodrigo et al., 2008). For example, a +0.8 score of an A–B transition is equivalent to an 80% likelihood that play state B will follow play state A. We adopted a 10% (0.1) cut-off point to determine meaningful sequences of play patterns so that positive interactions were reported. Figures 5–8 show these results for all conditions. The thickness of the bars, linking behavioural states, shows the strength of the likelihood of an interaction occurring. Where there is no arrow between the types of behaviour, interaction was not significant.

Figure 5 Interaction of children with autism with the KC

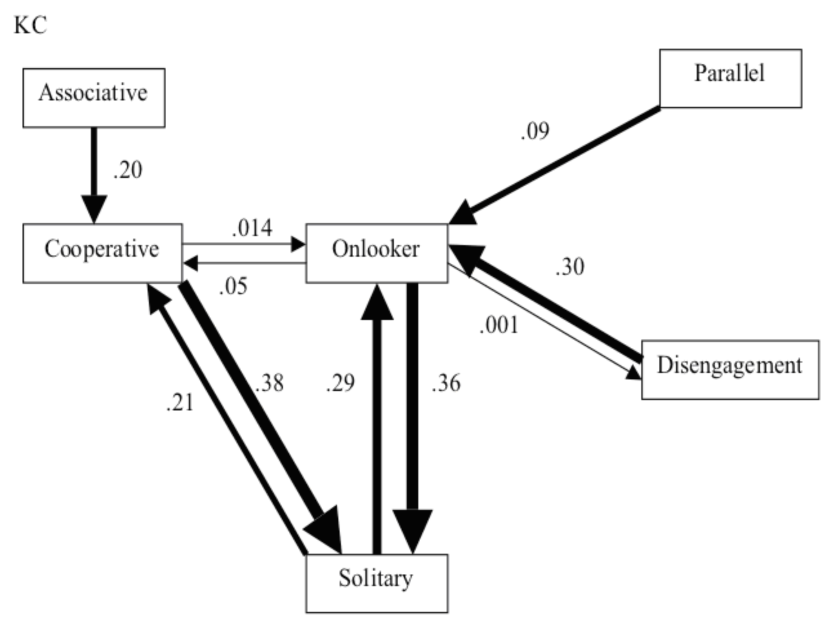


Figure 6 Interaction of children with autism with the AKC

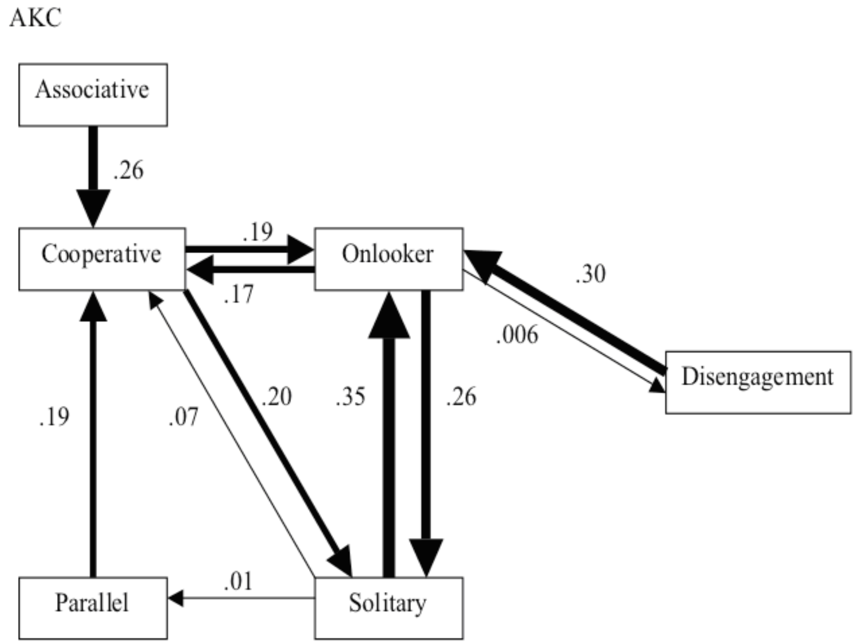


Figure 7 Non-configurable AKC interaction

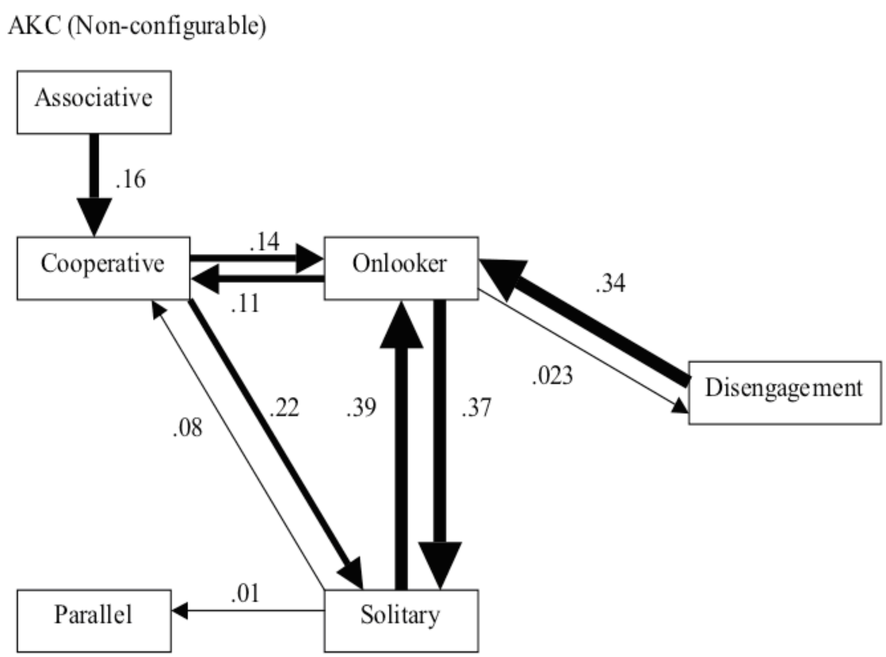
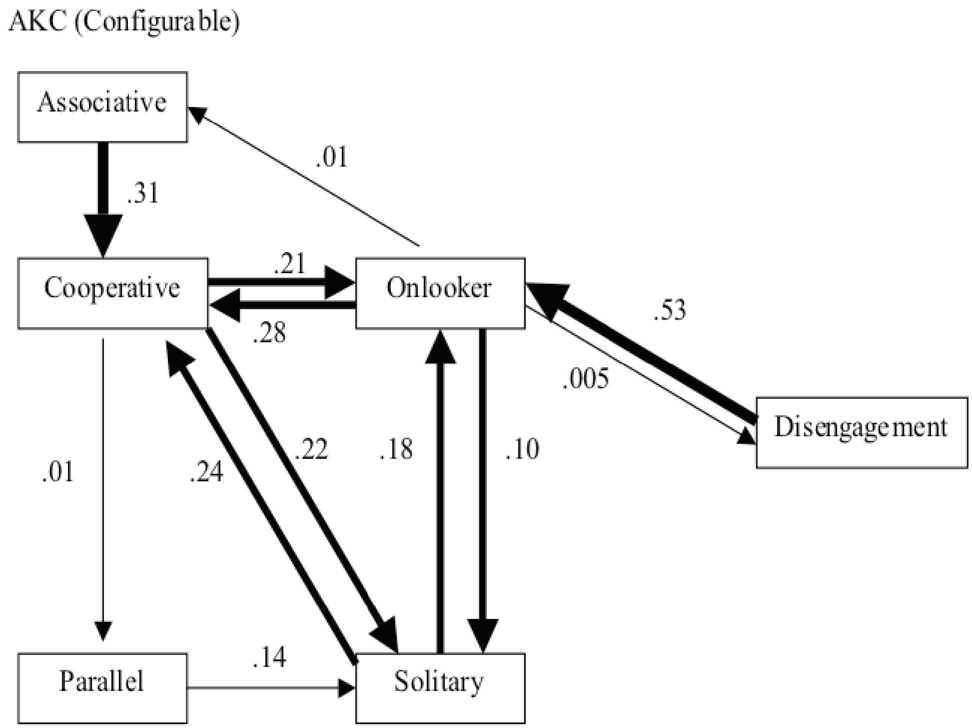


Figure 8 Configurable AKC interaction



6.2 KC compared to AKC

A Wilcoxon non-parametric test of all durations of behaviour for the AKC showed that solitary behaviour was significantly less whilst playing with the AKC using a ($Z = -2.237$, $p < 0.02$) than with the KC. Frequency of solitary behaviour was also significantly less with the AKC ($Z = -2.197$, $p < 0.02$) than with the KC. Frequency of onlooker behaviour was more with the KC than with the AKC ($Z = -2.118$, $p < 0.03$). Comparisons of each social interaction picture (see Figures 5 and 6) show that more likely transitions of a play state may not indicate quality interaction when compared to varying play states. For example, social play with the KC breaks down when children cooperate, as they are most likely for transition to solitary behaviour (see Figure 5).

In effect, once children are playing cooperatively they move on the whole to solitary play (Figures 5). Although children exhibited more overall onlooker behaviour with the KC, the quality of interaction appears to be less than with the AKC (Figure 5). Solitary behaviour with the KC leads back to onlooker or cooperative states, but this is without the clear cycle of onlooker to cooperation loop that occurs more readily with the AKC. Parallel play leads to onlooker behaviour with the KC, but to cooperative behaviour with the AKC. When the AKC is switched on, children with autism appear to have more ways in which they get back to play cooperatively again.

Onlooker behaviour works differently for the AKC and KC; with the KC it can lead to disengagement, cooperation or solitary play. With the AKC onlooker play state leads to disengagement, cooperation and solitary play, but the likelihood of onlooker action leading to cooperation is greater. Children on the whole must go via onlooker behaviour to cooperation. The likelihood of solitary behaviour, leading back to onlooker behaviour also appears to be greater with the AKC than the KC.

6.3 *Configurable compared to non-configurable AKC*

AKC data from session 2 was analysed using the coding scheme in relation to the experimental condition of configurable vs. non-configurable AKC. A one-tailed Mann-Whitney two independent samples non-parametric test was used. Significantly less amount of time was spent in solitary behaviour with the configurable CAKC ($Z = -2.326$, $p < 0.01$) when compared to the non-configurable AKC. Significantly more time was also spent in cooperative behaviour with the configurable AKC ($Z = -2.882$, $p < 0.01$) in comparison to the non-configurable AKC.

The non-configurable AKC (NCAKC) allows for interaction between cooperative and onlooker behaviour (see Figure 6). The strongest interaction is the loop between onlooker and solitary interaction.

Disengagement leads positively back to onlooker behaviour, and onlooker behaviour does not lead necessarily to disengaged behaviour. Associative behaviour has a stronger likelihood of leading to cooperation. Solitary behaviour has a higher likelihood of leading to parallel behaviour.

For the configurable AKC (CAKC) disengaged behaviour is strongly linked to heading back towards onlooker behaviour (see Figure 7). There is a strong cycle for CAKC between cooperation, onlooker and solitary behaviour. The likelihood of cooperative behaviour leading to onlooker behaviour and back accounted for almost half of all potential transitions (0.53). Associative behaviour also has a higher likelihood (0.31 with CAKC as opposed to .16 with the NCAKC) of leading back to more positive social interaction of cooperation. The more even distribution of interactions in the configurable AKC condition – shown by bars being less thick – indicates a greater variety of ways children interacted.

6.4 *RFID figures*

Data were additionally collated on the number of times children used RFID figures to speak. An RFID figure was deemed to have ‘spoken’ when a child picked up a character and placed the character in a part of the AKC, and the AKC responded by playing a pre-recorded sound. Examples of what characters said include dragons roaring or the knight saying “I need a weapon, where is my lance”. When comparing the configurable with the non-configurable AKC, the amount characters were used to produce speech was 78 (NCAKC) with 229 (CAKC). The number of times the characters were used when the play set was configurable suggests that the ability to be able to configure made play with figures more likely.

6.5 *Object interaction, ability and children’s play*

An interesting significant effect was found for CARS scores between the CAKC and NCAKC conditions. This may have been a possible hidden variable that may explain differences in the quality and quantity of children’s play. A significant result showed for children’s ‘Object Use’ ($Z = -2.351$, $p < 0.02$, non-configurable-configurable) for the non-configurable condition, so children were more likely to show as is stated in question 5 of 'mildly inappropriate interest in objects'. If this is the case, children's play behaviour may simply be explained by object ability, and not the configuration of the AKC, switched on or off. This significant result was based on children's scores on CARS question 5. The data for this question was analysed further, using a one-way ANOVA and showed the same significant effect ($F = (1, 10)$ 9,474, $p < 0.01$) but when CARS 5 was included as a covariate, this was no longer significant for children's play states in either condition (e.g. solitary play between conditions $F = (1, 12)$ 0.740; $p = 0.41$). A multivariate analysis confirmed this ($F = 0.440$; $p = 0.77$). Whilst it appeared that children's ability to be able to play with objects impacted on play behaviour, it was not the case here. Whilst not impacting on this data, this is an interesting aspect of autistic children's interaction with the AKC, in that initial object ability may point towards children's initial abilities with tangibles.

Although the ability to use an object had no significant impact on either group, the difference in use of the RFID figures between groups is large. In the configurable condition children interacted with figures more often.

Overall the CAKC and the AKC:

- seemed to offer multiple entry points to play states
- led to greater character use, but it is unclear if this is symbolic or functional use
- allowed for more opportunities for play to become more cooperative.

7 Qualitative results

Here, we discuss four key qualitative findings; learning phase, user content, behaviour oriented to other children and system responsiveness. Findings here focus on key discoveries during the configured play sessions that captured interaction features important during children's play.

7.1 User content

The opportunity to input own content on to the AKC provided children with a powerful interactive tool. When the system worked as intended with user content given immediately, this prompted more interaction within the group as children then looked to their peers for approval and discussion about the effect. As mentioned above, this typically took place after about 5 min as in this example. In this example, children are reaching the point where they understand how the system works and so start to think about the type and placement of user content as a group with little prompting:

[00:05:21.18] Adult 1: Where's it going to be?

[00:05:24.10] Child 1: At the dragon's tower

[00:05:25.20] Child 3: Inside it or?

[00:05:27.29] Child 2: He wants to just play with the dragon (dragon figure growls)

[00:05:32.24] Adult 1: Oh it did not work we're going to have to do it again

[00:05:32.24] Child 1: (tries out dragon)

[00:05:36.19] Child 1: I don't mind doing it

[00:05:36.19] Child 3: I'll do it. Can I try again?

Children's motivation with the AKC was equally influenced when they could hear or show their own content.

[00:02:49.03] Adult 1: Are you ready to record?

[00:02:49.10] Child 3: Roars (whilst playing with dragon) Yeaahhhhh. Look

[00:02:55.19] Child 1: (Recording) 'I am going to suck your blood'

[00:02:58.00] Child 3: What? (Looks over at what child 1 is doing) What did you say?

The impact of using and making content produced joy and excitement amongst users far more than pre-configured sounds; however, characters in the NCAKC were more likely to be seamlessly played within the castle setting, which led to more symbolic play, where children played imaginatively and made up stories of characters interacting. With the configuration, children were more interested in programming as a part of play. Configuration may have impacted on children's symbolic play, as children diverted imaginative activities to establishing user content.

7.2 Learning phase

Children learnt to use the AKC at the end of session 1, and in session 2 this was either extended or added to in the form of the configured or non-configured AKC.

Results found during the second play sessions may be due to the effect of learning to configure. Variance in quantitative interaction may equally have grown or lessened if there had been a third session. Yet children's attempts to configure were dependent on learning the system. In this example, the child is being taught how to configure:

[00:00:05.10] Adult 1: You got one? Right so if you put that in the box. Now… can you see that there? It's the black knight

[00:00:23.09] Child 1: Yeah

[00:00:21.09] Adult 1: Now what we are going to do is we are going to programme the knight to say something. What do you want the knight to say? When I say start you speak into there (points to microphone) something that you want the knight to say. Okay? Go.

[00:00:47.14] Child 2: (Laughs then says) 'Die all of you'

[00:00:50.14] Adult 1: Okay? So this is what it will sound like. Listen? (Plays back 'Die all of you')

[00:00:52.24] Child 1: (Laughs)

[00:00:54.09] Adult 1: I am going to store that. Now where do you want that to actually happen?

[00:01:10.25] Child 2: (Puts toy in front of the cave)

Towards the end of sessions children needed far less guidance:

[00:17:51.15] Adult 1: Where is this going to happen? Where is the laugh going to happen? (The dragon had been programmed with user content)

[00:18:02.12] Child 3: Up there up there (points to top of dragon tower)

[00:18:02.12] Adult 1: On top of the dragon tower

[00:18:04.24] Child 2: He is too heavy

Even though children were learning to configure in session 2, interaction between children was not impacted upon. However, most children were able to pick up how to configure within the first 5 min of the play session. So learning phase was steep and quickly achieved.

7.3 Behaviour oriented to other children

Children often took on roles whilst playing with either the CAKC or NAKC, and often these roles were interchangeable. However, with the CAKC if one child lost interest in play, another child would try and encourage that child to become involved again by taking and showing them a Playmobil character and/or demonstrating an effect with the AKC, possibly due to user content driving play. Roles also extended as far as who led the play if children were inventing a story. This storyteller's role was also interchangeable. With the AKC demonstration of programmed effects became a key part of the configured AKC, as showing and sharing caused laughter and amusement as children tried to install exciting and interesting effects within figures. This demonstration often led to that child being the focus of interaction around the AKC. With the non-configurable AKC, this type of role changing and centre of attention action occurred less obviously, so children were more likely to assert themselves in the configured condition. Here, in the CAKC, child 3 draws the attention of child 1 as he is programming content on to the red dragon; child 2 becomes involved at the end as he tries to gain the other children's attention by making the sound of an animal, which he subsequently programmes on to the AKC:

[00:16:59.09] Adult 1: Okay what are we going to have said. What's it going to be: 'I'm the big red dragon'

[00:17:20.06] Child 3: No no it's 'ha ha hah'

[00:17:20.06] Child 1: No no it's 'Mwah hah hah'

[00:17:23.09] Adult 1: Ready

[00:17:23.09] Child 3: Ready

[00:17:23.09] Adult 1: Okay. Steady

[00:17:25.08] Child 3: Wait wait

[00:17:27.29] Adult 1: Do you know what you saying? What is it you are saying?

[00:17:29.29] Child 3: 'Mwah hah hah'

[00:17:30.25] Adult 1: Yeah okay 1,2,3

[00:17:34.26] Child 3: Mwah hah hah

[00:17:36.04] Adult 1: Right you want to hear it

[00:17:38.19] Child 2: Ba ba baaaa

With the non-configured AKC, it was often less about demonstrating effects than about placing the effects within a story scenario. If anything the configured aspect of demonstrating programmed effects shows that children needed time to investigate the novel elements of the technology.

7.4 System responsiveness

Feedback of the AKC occurs on 2.5-sec cycle that has been reported elsewhere (Hinske, 2009). Whilst this is as fast as possible within the current design, there is a time lag between children placing figures and receiving feedback. Any lengthy lapse in feedback always produced problems for children in that they were disappointed if the effect was slow. They were also equally disappointed if the feedback given was not what they had individually programmed. Figures programmed are given a probability of playing from 1 to 10. In the configured condition, all programmed characters were given a probability of 10 but sometimes pre-configured sounds still played. This produced confusion, but not frustration. When sounds were played children's reactions varied from laughing, to high fives, to wanting to do more programming, as in this example from session 2 of the configurable condition:

[00:02:46.15] Child 1: Do I have to say it first?

[00:02:49.03] Adult 1: No. We'll just do it. Are you ready to record?

[00:02:55.19] Child 1: 'I am going to suck your blood'

[00:02:58.00] Child 3: What? (Looks over at what child 1 is doing) What did you say?

[00:02:59.25] Adult 1: Okay now where is this going to happen?

[00:03:05.10] Child 1: At the top of this

[00:03:12.17] Adult 1: At the top of the...

[00:03:12.17] Child 1: You know the cave…at the top of the... (points)

[00:03:12.17] Adult 1: At the top of the cave

[00:03:12.17] Child 1: Yes at the top of the cave

[00:03:30.16] Child 1 places RFID character: 'I am going to suck your blood'

[00:03:32.19] Child 1: laughs

[00:03:32.19] Child 3: looks up and also laughs – looking at child 1

[00:03:35.01] Child 1 and Child 3 High five between two children

[00:03:36.21] Child 1: laughs

However, even delay between placement and feedback created an opportunity for social interaction as when the system was deemed not to be working, answers were sought from the experimenter.

The four areas of qualitative finding show that

1 user content prompted interaction by users
2 children needed to learn how to configure, but this did not impact on the amount of interaction
3 behaviour became more oriented towards others with the CAKC as children sought each others attention
4 that system response provided immediate feedback which motivated children to continue to interact.

8 Discussion

In this study, the aim was to see whether allowing configurability of the AKC for children with autism changed their social interaction. This was also compared to when the AKC was switched on as well as off for all children to see if there was a difference in the quality of interaction. Children with autism appeared to benefit from an extension of object affordance with tangibles through digital effects. Predictable and personal content playback created a higher quality experience. Whilst the KC alone is still an important and good toy – as it should be – as shown in Figure 5, the addition of digital effects raises the bar in terms of quality interaction. Inputting user content appears to create more opportunities for interaction amongst users. Other research has demonstrated the importance of user content with tangibles, but with the deliberate purpose of story making like Picture This! (Vaucelle and Ishii, 2008). Here, we have sought to allow children the freedom to play with a toy environment with no particular end goal in mind. However, in terms of compensatory mechanisms, the actual configuration itself could be seen as a task or a goal, and so may have helped the children's behaviour with the AKC. More orientation, more motivation and more positive social interaction in the form of cooperative behaviour may have been aided the focus of the play sessions being on 'configuring' as opposed to simply playing. Nevertheless, the goal orientation of providing a task focus to the play session enabled children the opportunity to be more cooperative and less socially isolated.

Typically developing children when playing with the AKC report that they would equally like additional control over content by switching on or off (Hinske et al., 2009). In this study, we went further than simply discussing digital vs. non-digital but sought to ask whether personal content would increase control over the AT and increase interaction. Whilst interaction like cooperation increased, and solitary behaviour decreased, more importantly the AKC provided more entry points for play when allowing for configured user content. Results in earlier work, using Topobo are similar to the AKC in that social interaction increased whilst solitary play decreased (Farr et al., 2010).

Using object interaction with TUIs provides additional insight into the behavioural structures that underpin autism. The social interaction that occurs around tangibles shows that the future for TUIs as a compensatory mechanism can be rich. Children can fundamentally play with them as they wish, especially as they are not hindered by a screen or physical limitations. Tangibles appear to provide a safety net of multiple entry points, helping children who may be at variant developmental stages and so prefer toys. End-user programming, in particular, allows children to programme as they go, again giving choice and freedom to when this occurs (Edge and Blackwell, 2006). Children who are challenged by speech as well as by object manipulation have an equal chance of playing with the AKC in an involved way. The lack of reliance on one type of access point allows broader access than research where digital effects are virtual or rely on speech (Tartaro and Cassell, 2008). Exploratory contexts can be better for social interaction when less reliance is on computational activity (Shaer et al., 2004). Touch and manipulation through haptic interaction is not new to TUIs, but has only recently become a priority for medicine and is clearly an important way forward (Vaucelle et al., 2009).

Exploration of objects that have digital effects can in certain circumstances, like with the AKC, map on to deficits present in disorders like autism. These TUIs would, on the whole, need to be familiar in form to children and less abstract, and take advantage of experiences through habituation (Jones and Smith, 2005). Digital effects should extend logically from the form of the object to exaggerate possible benefits.

A key question remains as to whether the effects found in this study would continue over time or if they were simply due to the novelty of the equipment. Longitudinal studies would address this shortfall in findings.

9 Conclusion

Overall results found that the AKC prompted:

- greater occurrence of behaviour, which was oriented to others when the AKC was configurable
- individual user content increased interest in the system and other children
- system responsiveness had positive as well as negative effects, children may want, children could switch off all digital aspects
- more parallel and cooperative play, and less solitary play with the configurable AKC
- more activity with Playmobil figures when children used the configurable AKC.

If children with autism struggle to understand the world around them, then control over their own environment must present them with daily challenges (Williams, 2004). Presenting an opportunity for increased configuration may well offer new avenues to children with autism through an increased sense of control (Rotter, 1989). Tangibles with multiple access points, when coupled with personally configurable elements, lessen isolation for children with autism. There is potential for systems like the AKC to be used in a therapeutic way. Diagnostic evidence could be compiled, where children with disabilities could then be appropriately compared to a typically developed baseline. Borderline diagnosis and confusion over the triad of impairments could be avoided, as harvested data could then be used in addition to observable reports.

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