In My Own Words: Configuration of Tangibles, Object Interaction and Children with Autism

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ABSTRACT
An Augmented Knights 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, less solitary play and more cooperative play occurred. Configurability is a key factor 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.

Categories and Subject Descriptors
H.5.2 [User Interfaces] (H.1.2) Interaction styles – *direct manipulation, user-centred design*

General Terms
Design, Experimentation, Human Factors, Theory

Keywords
Configuration, Tangibles, Autism, Object Interaction, Social Interaction

INTRODUCTION
Augmented and tangible toy interfaces offer a variety of feedback mechanisms from visual engagement and kinesthetic interaction, to audio and haptic feedback [6, 10]. Tangible user interfaces allow for a variety of mappings between physical and digital space [e.g. 22]. These multiple entry points could be beneficial for children with autism [1, 12].

Digital technology often appeals to individuals with autism, and can help redress some social deficits [e.g. see 2]. An impaired ability to predict change in human behaviour relates directly to behavioural mapping, or the cause and effect of a tangible [1, 29]. Autistic children are additionally affected not only by social difficulties but are impaired in their understanding of object interaction [15, 23, 32]. Therefore predictable cause and effect in tangible systems has the potential to support person-to-object-to-person interaction.

Figure 1. The Augmented Knights Castle play set.

Here we investigate the hypothesis that an Augmented play set that can be configured by children with autism will increase social interaction. Feedback can be changed by the user if allowed to input content, which increases user control [19]. The Augmented Knights Castle play set was used to see whether configuration of the AKC increased children's social engagement when children with autism controlled feedback and could program where, when, and what RFID figures said.

Autism, Predictability, and TUIs
For a child with autism the world is made up of a confusing array of factors and ongoing incidents that require the constant testing-out of ideas [31]. Computers allow children with autism a chance to encounter tools and symbols that can support social interactions. Computers contrast with human behaviour because they do not react to the odd behaviour typically found in autism [15]. Stress and unpredictability caused by social interaction are largely removed in computer interaction [13]. Tangible user interfaces and augmented toys are input/output devices with multiple entry points. Entry can be made by physical manipulation, observation of digital effects, listening, talking, and playback of digital features. The clear

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functionality due to pre-designed cause and effect lends itself more to social than isolated interaction.

Object Interaction & Autism

Most object use with children occurs during play. We define play as the motivation for an action being the process in of itself [11]. Moreover, children more often than not play with human created objects [11]. Artificial objects, such as tangibles and augmented toys can be used to extend logically from an object's function and appearance to provide a high-quality experience, whilst minimizing confusion as they are predictable in their digital effects unlike human interaction [1, 23]. Toys are play objects that are familiar, and with the addition of digital technology provide quality materials for play. For example, Topobo [16] when linked together forms objects that look like animals and insects, and when programmed it 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 [4] .

Children with autism experience difficulties in understanding how to use objects flexibly in social situations [32]. Object use is often a social process which children with autism find difficult [32]. Functional or sensori-motor use of an object is easier for a child with autism to understand than that of symbolic use [20]. Symbolic use of objects occurs when children play and develop imaginary situations [11]. Playing with objects is repetitive and often inflexible with low levels of exploratory behaviour [14]. Proximal senses such as touch with the hand or mouth are favoured to gather information as opposed to auditory or visual means [30]. Without a clear understanding of the functional use of an object, features and aspects often become fixated upon, [29].

For children with autism frequency and quality of object play depends on the type of object and the structure of the situation [25, 30]. Pairing children with severe autism with an adult playing with an object in parallel increases interaction during positive imitation [25]. Greater frequency and duration of play also occurs depending on the play material and structure employed [25]. 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:

- 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

Augmenting toys and tangible user interfaces

Tangible user interfaces (TUIs) are objects with digital technology embedded. TUIs are found in graspable forms, and allow access to computer technology through objects [9]. The possibility of manipulating objects through digital and physical actions introduces a novel element into user action [26]. A tangible interface for children with autism may promote co-located cooperative work [26]. TUIs encourage reflection and discussion about the objects as they are used. Digital and physical effects in TUIs can often be recorded, and this record of change has been shown to help individuals focus on activities [8].

Augmented toys use the aforementioned aspects because they allow children to trigger and configure digital content. The AT in this current study, the AKC, allows toy figures to be played with that speak, but also allows these figures to be programmed with children's own voices.

The Augmented Knights Castle

Figure 2. The Augmented Knights Castle showing dragon tower, castle, magic pool, and internal system showing RFID technology.

The Augmented Knights Castle (AKC) is an augmented toy environment consisting of three base units that are wirelessly connected to a system server. An earlier version consisted of one centralized play set [10]. The base units are equipped with radio frequency identification (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 1.5cm 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 occurs almost in real time.

Figure 3. The Augmented Knights Castle showing internal system RFID technology, antennae (right hand side) multiplexers, and surround sound inside main section.

METHOD

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 up of boys (two groups aged 12-13, and one group aged 9-10) one group of autism year 5 was made up of 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 [21]. 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.

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 recognized each figure using RFID tags. The option to speak into a microphone and program each figures speech was available. The researcher programmed the location where a character would speak, but children eventually learnt this.

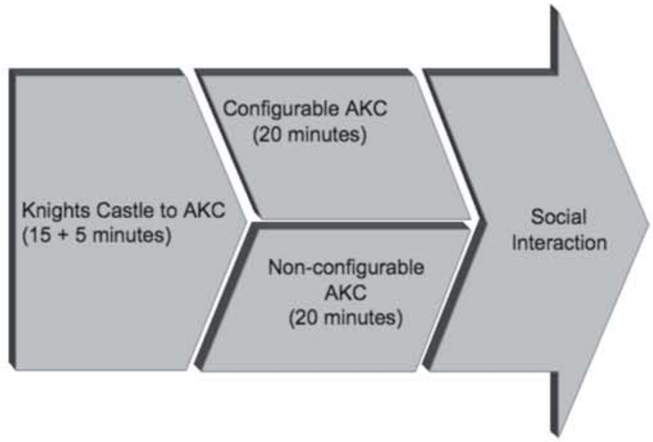

Figure 4. Experimental method

Stimuli and apparatus

Children's play sessions were recorded using a digital video camera. Sessions took play in a room $4m^2$ 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.

Procedure

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

Session 1

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 minutes 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 twenty minutes 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 twenty minutes again to play with the AKC.

Configurable AKC condition: You have twenty minutes 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 twenty minutes again to play with the AKC.

Coding

Videotapes were coded using Mangold Interact™ software, using a coding scheme shown in Table 1 [modified from 14, 17]. 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 25]. This coding scheme provides a descriptive account of play suitable for both groups of children in clear play patterns. This coding scheme has been used before [4] but was now modified including recent research to allow for more recent development and clarification on particular codes such as solitary and parallel behaviour [see 7, 20]. Inter-rater reliability yielded a κ of .78 on a coding sample of 30% of all video.

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

Table 1. Coding method

QUANTITATIVE RESULTS

Autistic Children's Play with the AKC

All individual data from analysis was broken down according to play state frequency and duration.

We also 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 was converted into a D'Mello score [3]. This 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 [18]. 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 4 to 7 show these results for all conditions. The thickness of the bars linking behavioural states shows the strength of the likelihood of an interaction occurring.

Configurable compared to non-configurable AKC

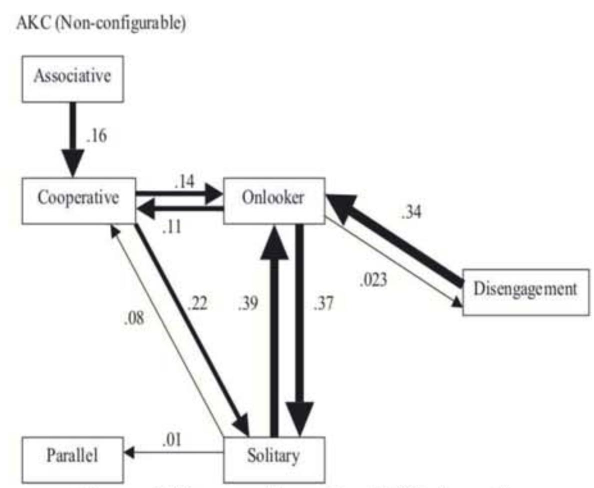

Figure 5. Non-configurable AKC interaction

AKC data from session 2 was analysed using the coding scheme in relation to the experimental condition of configurable versus 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 ($Z=-2.326$, $p<0.015$) when compared to the non-configurable AKC. Significantly more time was also spent in cooperative behaviour with the configurable AKC ($Z=-2.882$, $p<0.002$) 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 toward onlooker behaviour (see figure 7). There is a strong cycle for CAKC between cooperation, onlooker and solitary behaviour. The likelihood of cooperation leading to onlooker behaviour and back accounted for almost half of all potential actions (.53). Associative behaviour also has a higher likelihood (.31 with CAKC as opposed to .16 with the NCAKC) of leading back to more positive social interaction of cooperation. There is also a more even spread amongst the interactions, shown by the bars being less thick, indicating more ways for children to interact around the CAKC.

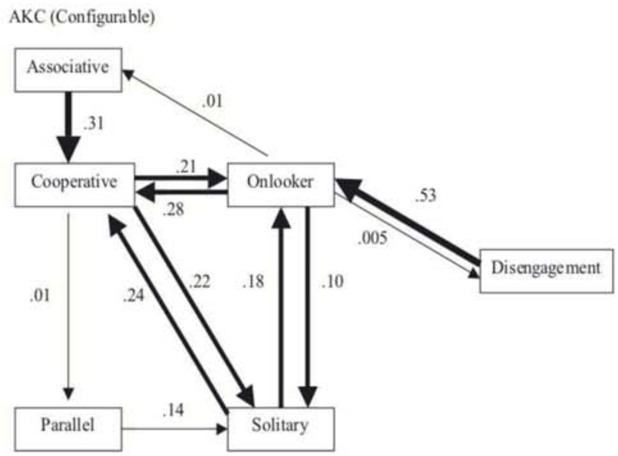

Figure 6. Configurable AKC interaction

RFID figures

Data was additionally collated on the number of times children used RFID figures to speak (see table 3 and figure 2). 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 (see table 2).

What the character says:	Character
"Roar"	Dragon
"I have served the king for over twenty years"	Knight
"I need a weapon where is my lance"	Knight

Table 2. Examples of RFID pre-recorded sounds heard in study

Condition	RFID characters use in 20 minutes
Non-configurable AKC	78
Configurable AKC	229

Table 3. Raw data for RFID characters

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:

- 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

QUALITATIVE RESULTS

Here we discuss four key qualitative findings; user content, learning phase, behaviour oriented to other children and system responsiveness.

User Content

The opportunity to input own content onto 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. 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 preconfigured sounds. However, characters in the NCAKC were more likely to be seamlessly played with in 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.

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 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 program 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)

Toward 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.

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 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 onto 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 programs 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 am 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.

System Responsiveness

Feedback of the AKC occurs on 2.5-second cycle that has been reported elsewhere [1]. 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 preconfigured 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, a) user content prompted interaction by users b) children needed to learn how to configure, but this did not impact on the amount of interaction c) behaviour became more oriented toward others with the CAKC as children sought each others attention and d) that system response provided immediate feedback which motivated children to continue to interact.

DISCUSSION

In this study the aim was to see whether allowing configurability of the AKC for children with autism, changed their social interaction. Children with autism benefited from an extension of object affordance with tangibles through digital effects. Predictable and personal content playback created a higher quality experience. 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 storymaking such as Picture This! [28]. Here we have sought to allow children the freedom to play with a toy environment with no particular end goal in mind.

Typically developing children when playing with the AKC report that they would equally like additional control over content by switching on or off [5]. In this study we went further than simply discussing digital versus non-digital but sought to ask whether personal content would increase control over the augmented toy and increase interaction. Whilst interaction such as cooperation increased, and solitary behaviour decreased, more importantly the AKC provided more entry points for play when allowing for configured user content.

Using object interaction with tangibles provides additional insight into the behavioural structures that underpin Autism. Tangibles appear to provide a safety net of multiple physical entry points, helping children who may be at variant developmental stages and so prefer toys. 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 [24]. Socio-constructivist concepts suggest that exploratory contexts can be better for social interaction when less reliance is on computational activity [22]. 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 [27]. Exploration of objects that have digital effects can in certain circumstances, such as with the AKC, map on to deficits present in disorders such autism. These TUIs would on the whole need to be familiar in form to children, and less abstract, to take advantage of experience through habituation. 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.

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 of 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 [31]. Presenting an opportunity for increased configuration may well offer new avenues to children with autism through an increased sense of control [19]. Tangibles provide multiple access points, and when coupled with personally configurable elements, isolation for children with autism seems to lessen. There is potential for systems such as 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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