



**Talkii – a speech-generating device changing the social and verbal
behaviour of children with autism spectrum disorder**

A mixed-methods case study from Luxembourg

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Abstract

Children with autism spectrum disorder (ASD) experience several significant impairments, including, in most cases, severe communication deficits and difficulties developing functional language. This can cause challenging behaviours, including self-injuring behaviour, aggression and frustration, due to the inability to express themselves. Nevertheless, students with language impairments can benefit from augmentative and alternative communication (AAC) systems to help them express their needs and desires. This study focuses on Talkii, a recognised AAC speech-generating device that has been developed in Luxembourg. Through a combination of observations of five students with ASD who use Talkii and seven semi-structured interviews with teachers and speech therapists who supervise these students, this study evaluated the effects this device has on the social and verbal behaviour of students with ASD and whether Talkii can enhance their communication skills. The results show that Talkii is effective in teaching students with ASD a functional verbal behaviour, including the five verbal operants mand, tact, echoic, autoclitic and intraverbal. Besides, findings regarding changes to the social and verbal behaviour of students with ASD indicate decreases in aggression and self-injuring behaviour as well as an increase in happiness, self-regulation and development of the personality. These findings highlight that Talkii appears as a good alternative when considering the use of a speech-generating device to support children that experience communication impairments.

Keywords: Autism Spectrum Disorder – Verbal behaviour – Social behaviour – Speech-generating device – Talkii

Introduction

When one thinks about autism spectrum disorder (ASD), one may think first about the main character of the movie *Rain Man*, Raymond Babbit. This character is best known for his encyclopaedic knowledge, calendar-calculating abilities and ability to read extremely rapidly by simultaneously scanning one page with the left and the other with the right eye. However, this so-called ‘savant syndrome’ is very rare, and only a few people with ASD represent such ‘islands of genius’ (Treffert, 2009). Although almost every individual with ASD is surprisingly good at something (Frith & Happé, 2005), the disorder is characterised by many significant impairments (van der Meer & Rispoli, 2010). For instance, children with ASD often show a significant delay in speech and language development (Achmadi et al., 2014), and most possess such limited expressive language skills that they are unable to communicate their needs and desires (Sigafos et al., 2003). This can cause some challenging behaviour in these students, such as increased frustration or aggression (van der Meer & Rispoli, 2010). Nevertheless, students who face communication impairments can benefit from augmentative and alternative communication (AAC) systems to help them express verbal behaviour (Achmadi et al., 2014; Agius & Vance, 2016). Recently, Sovi Solutions, a start-up company from Luxembourg, launched a new AAC device on the market called ‘Talkii’. Talkii is a speech-generating device (SGD) which helps to develop a child’s language and encourages them to grow their skills in communication (Jonk Entrepreneuren, 2020). In this research, Talkii is the main target of interest. Analysing how students with ASD use Talkii to communicate reveals the effect this SGD has on such students and their social and verbal behaviour.

Core characteristics of autism spectrum disorder

The core impairments of ASD impact the development of a person and are diagnosed at younger ages based on social and communication impairments and rigid or repetitive

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patterns of social behaviour and interests. In recent years, ASD has been seen as a spectrum of disorders that can range from very mild to severe (Frith & Happé; 2005; Lord et al., 2018). For example, Asperger Syndrome characterises individuals who have autistic attributes but without the accompanying delay in language and intellectual development. One of the most enigmatic core features of ASD consists of being blocked into an egocentric stance, which renders individuals unable to understand other people's minds or realise when others are mocking them (Frith & Happé, 2005). Research shows that this behaviour can be best explained by the theory of mind, which defines people with ASD as 'mindblind'. People who do not lack this ability are able to "infer the full range of mental states" (Baron-Cohen, 2001), including beliefs, desires, intentions, imagination and emotions.

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Moreover, children with ASD often experience multiple deficits in language and communication development (Agius & Vance, 2016; Muharib & Alzrayer, 2018). Research shows that up to half of children with ASD do not develop speech at all or only develop limited speech and language abilities. Most such children only communicate through communicative behaviours, like pointing, reaching, or facial expressions (van der Meer & Rispoli, 2010). This communicative behaviour recalls Chomsky's theory of language, which suggests that language is an innate skill with which human beings are born. Chomsky refers to this set of inherent rules of language as Universal Grammar (UG), which consists of a system of principles, conditions and rules that are elements or properties common to all languages. He describes UG as the essence of human language, meaning that all human beings have some knowledge of language (Barman, 2012), even if they are unable to communicate verbally, as some people with ASD are. As a result of their difficulties in communicating their needs and feelings, the frustration level of children with ASD can increase because they often feel misunderstood (van der Meer & Rispoli, 2010). Therefore, children with ASD are at a higher risk of displaying challenging behaviours, like aggression

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or self-injurious behaviour (Muharib & Alzrayer, 2018). Often, it is unclear whether the lack of speech such children with ASD display at a young age will remain as they grow older (van der Meer & Rispoli, 2010).

Nevertheless, children with ASD can benefit from various interventions that allow them to enhance their communication skills in their daily life. Here, Skinner's theory of verbal behaviour appears crucial, as he has described several verbal operants that are widely used when teaching functional communication skills to students with ASD (Johnson et al., 2017). According to Skinner, verbal behaviour entails the producing and mediating functions of language responses, like speaking, singing, gesturing, etc. (Greer, 2008). This means that verbal behaviour is behaviour that is emitted by a speaker and mediated by a listener. Skinner argues that the function of the verbal behaviour is of most interest (Lorah et al., 2015). Unlike Chomsky, Skinner proposes that humans communicate because their communication is strengthened or weakened by the consequences that an audience or listener provides (Johnson et al., 2017), which means that behaviour is understood as a function of the environment or setting (Barman, 2012).

In his theory, Skinner defines five verbal operants that build on different functions (see Table 1). The first verbal operant, mand, which is an abbreviation of the words 'command' and 'demand', describes the functional communication skill of requesting a desired item. Children may request a certain object, as there is an antecedent condition, such as hunger or thirst, that motivates them to make the request (Johnson et al., 2017). Single-step requests are made by stating the desired item and multi-step requests by formulating a whole sentence (Agius & Vance, 2016). The second verbal operant in this list is an echoic, whose main function is to imitate a sound pattern similar to the heard stimulus (e.g., the vocal speech of a communication partner). Skinner also describes an echoic as a "point-to-point correspondence". Intraverbals are described similarly, but in fact, in their case no point-to-

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point correspondence is evoked; instead, another verbal response occurs, such as in the following exchange: “What do you want for lunch?” asks the teacher; “Spaghetti bolognese”, responds the child. This type of communication appears to be an extension of the verbal repertoire of children with ASD, because they can increase their social communication repertoires through conversations (Johnson et al., 2017). This verbal operant recalls the picture exchange communication system (PECS) protocol of Frost and Bondy (Agius & Vance, 2016), which is discussed in a later section of this paper.

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Table 1. Verbal operants from Skinner’s theory of verbal behaviour

Operant	Description	Example
Mand	Someone requests a desired item.	Student says: “I want an apple”.
Echoic	Someone imitates a vocal model.	Student says: “Mama” after his mother has said “Mama”.
Intraverbal	Someone verbally responds to a question or statement made by the communication partner.	Mother asks child: “Are you hungry?” Child responds: “Yes”.
Tact	Someone labels an item or states the name of a person.	Student says: “Mama” by pointing to his mother.
Autoclitic	Someone uses an adjective or adverb to make a request for a desired item or person and/or label this item or person.	Mother says: “Do you want grape or orange juice?” Child responds: “Orange juice”.

(Johnson et al., 2017)

Furthermore, Skinner defines the verbal operant tact, which is a response to a particular object or event found in the environment. The word tact consists of the abbreviation of the word 'contact' and is inspired by the idea that verbal behaviour is evoked when a speaker comes into contact with a stimulus in their environment, such as when a child sees a horse and says "Horse". The last verbal operant is the autoclitic, described by Skinner as verbal behaviour that depends upon other verbal behaviour, such as an adjective or adverb form. Using an autoclitic allows a child to make an even more precise request and choose one from a range of different objects, such as "I want the red ball", which gives the listener a hint that the child does not want the orange ball (Johnson et al., 2017). These verbal operants build the foundation of the analysis of this study, as they seem important when teaching functional communication skills to students with ASD, including the use of an AAC system to support their verbal behaviour.

Augmentative and alternative communication systems

Communication skills can be supported with the application of AAC systems (Agius & Vance, 2016; Kagohara et al., 2010; Muharib & Alzrayer, 2018), which refers to the practice of either supplementing (i.e., augmenting) or replacing (i.e., offering an alternative to) natural speech (Lorah et al., 2015; van der Meer & Rispoli, 2010). The goal of AAC interventions is to assist people with communication disorders to become more communicatively competent in daily activities, enabling them to develop generalised functional verbal behaviours (Mirenda, 2001), such as the five different verbal operants defined by Skinner outlined above (Johnson et al., 2017; Lorah et al., 2015)

AAC systems are generally classified into unaided and aided systems (Agius & Vance, 2016). Unaided systems, like manual sign language, do not require any equipment; rather, they only need the body of an individual (Mirenda, 2001). For example, the manual sign for 'more' is often used by children with ASD to indicate how long they want to play or

continue a certain activity (Achmadi et al., 2014). However, manual sign language has several disadvantages, as well-developed motor skills are needed that people with ASD often lack. Moreover, not everyone understands manual sign language, which hugely limits the natural environment of an individual with speech impairments (Lorah et al., 2015).

In contrast, aided systems require some sort of material or device that is external to the user's body, such as electronic devices, photographs or pictograms (Mirenda, 2001; van der Meer & Rispoli, 2010). A review study by Lorah et al. (2015) distinguishes several types of aided AAC systems, including picture exchange (PE), PECS, and SGDs (van der Meer & Rispoli, 2010). In PE, children are taught to communicate by exchanging symbols (e.g., pictograms) that symbolise a tangible item (e.g., apple), an activity (e.g., bounce on the trampoline), a response (e.g., yes or no) or a statement (e.g., "I am Laura") with their communication partner (Agius & Vance, 2016). PECS functions similarly to PE but additionally involves a sequenced training protocol in six phases (Sulzer-Azaroff et al., 2009). In phase 1 and 2, the focus lies on the nature of communication, meaning that the student learns to request a desired item (i.e., mand). In phase 3, discrimination between different symbols is taught so that the student is able to make a choice (i.e., autoclitic). At the end of this stage, students should be able to locate a symbol from an array and make independent requests (i.e., mand and autoclitic). After this stage, students learn in stage 4, 5 and 6 to build easy sentences (i.e., multi-step mand) and respond to verbal questions (i.e., intraverbal, tact and echoic) (Agius & Vance, 2016).

Third, SGDs are portable electronic devices that produce digitised or synthesised speech output. When the user puts their finger on the required symbol, the recorded voice of the device is activated (Kagohara et al., 2010; van der Meer & Rispoli, 2010) With this device, students are taught to touch whichever item they wish so the listener can understand from the digitised or synthesised speech output what they want (Achmadi et al., 2014). Here,

a common practice is to use the PECS protocol to teach students to use an SGD. A closer look at the different phases of PECS shows that they can easily be linked to the five verbal operants defined by Skinner (Agius & Vance, 2016; Johnson et al., 2017). Currently, the trend in AAC is toward the use of mobile technologies, such as Android tablets, touchscreen phones and iPads, which can be used as SGDs once an AAC application (app) is installed. A comparison of AAC systems reveals that SGDs have one huge advantage in contrast to PE, PECS or even manual sign language: the speaker is not required to gain the listener's visual attention before communicating. Through the digital voice output, the listener can interpret the request even if they are not directly looking at the speaker. Another advantage of SGDs is that, as they acquire a larger verbal repertoire over time, more icons can be stored in a much more compact and efficient manner; in contrast, PECS cards or PE picture symbols are easily damaged and non-practical to carry always with you (Lorah et al., 2015). In this research, the focus lies on Talkii, an SGD created and marketed by Sovi Solutions of Luxembourg.

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Talkii – AAC communication tool for people with special needs

Talkii is a customisable AAC tool that addresses all people with special needs, especially individuals with communication disorders such as those encountered in ASD, aphasia, verbal apraxia, etc. Talkii was created to offer an additional device for conventional AAC systems, such as PECS, PE and SGDs, that show similar functionalities. A unique feature of Talkii is that it entails two different applications: *Talkii Tab* (see Figure 1) and *Talkii Supervisor* (see Figure 2). A crucial feature of the Talkii Tab is that the application is blocked: the user cannot close the app or switch to another app, preventing children from using the tablet for other purposes (i.e., playing games). Talkii Supervisor enables parents or teachers to programme different features on the Talkii Tab, for instance the upload of pictograms (Sovi Solutions, 2021).



Figure 1. Talkii Tab

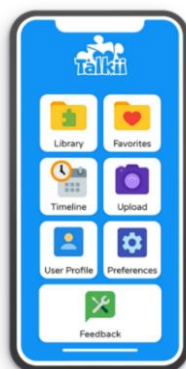


Figure 2. Talkii Supervisor

Furthermore, there exist several different layouts for the Talkii Tab, which can be easily changed by the Talkii Supervisor to meet the user's needs. It is up to the user which features are visible on the Talkii Tab. For example, only pictograms can be made visible for children who are easily distracted by too many functions. Under 'favourites' (see figure 4), the desired pictograms can be selected to be made available on the Talkii Tab. Only the selected pictograms will be shown on the Talkii Tab so that teachers and parents can decide what pictograms their child or student can or will use (Sovi Solutions, 2021).

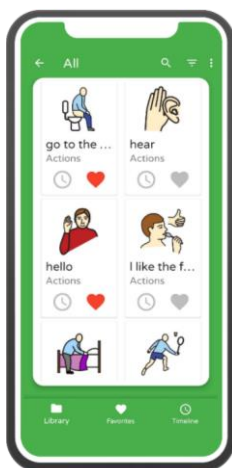


Figure 3. Library

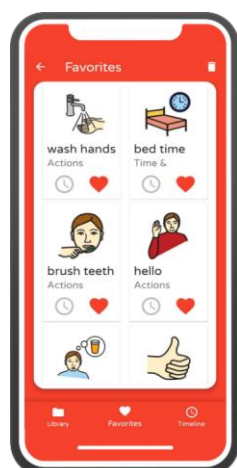


Figure 4. Favourites

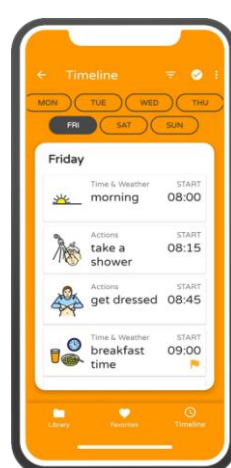


Figure 5. Timeline

Besides, several categories showing different pictograms are installed on the device and can be found in the 'library' (see figure 3). However, it is also possible to upload one's own images and photos that the Talkii Tab user may recognise (see figure 6). Hence, parents or teachers can create their own categories which are tailored to the special needs of the child. When the desired pictograms are defined as favourites (in the Talkii Supervisor application), they directly appear on the Talkii Tab and are ready to use. Sovi Solutions uses the synthesised Google voice, but it is also possible to record voices (see figure 7), which seems adequate, especially when a user's own images are added. This SGD is available in seven different languages, including English, French, German, Italian, Luxembourgish, Portuguese, and Spanish. Furthermore, Talkii offers an integrated 'timeline' that can be adapted to the individual plans of the student (see figure 5) (Sovi Solutions, 2021).

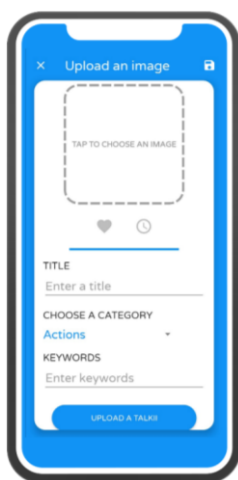


Figure 6. Upload image

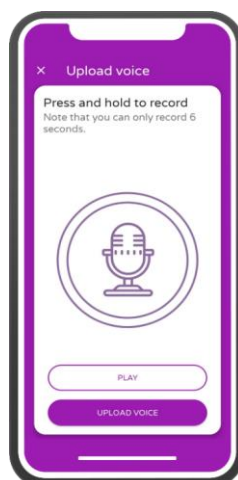


Figure 7. Upload voice

(All figures are taken from Sovi Solutions, 2021.)

Effects of SGDs on children with ASD

There appears to be abundant and rapidly expanding research about children with ASD who use SGDs to communicate, undoubtedly due to the growing use of electronic devices, including iPads or tablets, that can be used as SGDs (Kagohara et al., 2010; van der Meer & Rispoli, 2010). A literature review by Lorah et al. (2015) highlights the different aspects analysed in 17 studies, such as the acquisition of a mand or functional communication repertoire, the acquisition of other verbal operants (i.e., tacting or labelling), different teaching strategies, discrimination training, comparisons to other AAC systems and participant device preference. The results show that a vast majority of the studies only elaborate on the acquisition of mand. Studies that focussed solely on mand showed that most participants acquired the skill to make independent requests to obtain a desired item. One study even reported that participants experienced a decrease in aggression when they successfully learned to make requests (Lorah et al., 2015).

Furthermore, Muharib and Alzrayer (2018) published a meta-analysis that aimed to evaluate single-case studies using high-tech SGDs for children with ASD. The aim of the study was to measure the effect size of high-tech SGD intervention on verbal behaviour, including the different verbal operants defined by Skinner. The results showed that studies were conducted in several types of settings, such as schools, clinics and homes, or a combination of two or more settings. The samples mostly consisted of one to eight children who were diagnosed with either ASD or other (communication) impairments. The targeted verbal operants in the reviewed studies were manding, tacting and intraverbal, and the results of the meta-analysis highlight that most of the students were able to acquire these communication skills. The findings also show that some SGDs had small effects on students' vocal production and major effects on single-step manding (Muharib & Alzrayer, 2018).

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Overall, studies have already shown some interesting findings about the effects of SGDs on the social and verbal behaviour of students with ASD. Nevertheless, the findings have also revealed that more high-tech SGD studies are needed, especially within the natural routines of children with ASD, as most studies have been performed either in clinics or an unnatural setting. Thus, the embedding of these devices in a naturalistic context may facilitate the acquisition of the targeted communication skills. Additionally, future research should be designed in such a way that teachers and caregivers are the main interventionists in high-tech SGD studies, to make the intervention even more naturalistic for the participants. Last, most of the reviewed studies did not generalise communication skills across settings (Muharib & Alzrayer, 2018). Therefore, this study investigates the above-mentioned limitations of past studies, or the so-called gap. Thus, this research mainly focuses on analysing the effects of a new and specific SGD, the Talkii, on all five verbal operants defined by Skinner. Besides, both vocal speech and social behaviour are analysed to evaluate the effects of this device on the general, including the verbal and social, behaviour of students with ASD.

Present Study

The main aim of this study is to evaluate Talkii by analysing its effects on students with ASD, including changes to their verbal and social behaviour, the latter of which mainly consists of aggression, frustration, etc. For the study, it is crucial to pay attention to ensuring a naturalistic setting and to make generalisations of different types of behaviour across different settings.

The related sub-questions are:

- What verbal operants do children with ASD display when using Talkii?
- Which changes in the social behaviours of children with ASD are the result of using Talkii?

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Method

Research Design

A qualitative mixed-methods study was chosen to answer the research question. Qualitative semi-structured interviews with teachers and speech therapists involved with students with ASD were combined with field observations of students with ASD using Talkii. Observation was chosen as an appropriate method to gather the data, as the (changed) behaviours of students with ASD are much better understood when the researcher sees how Talkii is used in the field. Thus, comments from stakeholders could be compared to the observed behaviour(s) in the field (McNaughton Nicholls et al., 2014).

Participants

In the interviews, $n = 5$ teachers and $n = 2$ speech therapists from the Centre for Children and Youth with Autism Spectrum Disorder (CTSA) participated. Speech therapists usually see their students once a week during speech therapy, for a maximum of 30 minutes. In speech therapy, students are trained in communication skills and the use of communication systems (like PECS, SGDs or other AAC systems). Therefore, the speech therapist is usually the first person who uses Talkii with a student. Teachers were also very important for this study, as they have the closest contact with the students at school. They know their students very well and generally supervise them every day throughout the school year. Moreover, teachers were able to share their insights into the daily activities faced by students with ASD and how Talkii is used in the school. The five teachers had experience of between one and 12 years. On average, teachers had $\mu=5.8$ years of experience, with a standard deviation of $s=4.9$. Besides, teachers were selected from three different locations in Luxembourg. CTSA locations differ in grade and developmental status of the students. One of the five teachers was an assistant teacher, who supervises one child with ASD in a regular school. An overview of all the relevant characteristics of the participants can be found in table 2.

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Table 2. Participants in Semi-structured interviews

Participant:	Manon	Mara	Linda	Tania	Pia	Jenny	Pit
Gender:	Female	Female	Female	Female	Female	Female	Male
Role:	Teacher in CTSA	Teacher in CTSA	Speech therapist	Assistant teacher	Speech therapist	Teacher in CTSA	Teacher in CTSA
Years of experience:	10 years	1 year	13 years	12 years	1,5 years	3 years	3 years
Location	Weimers-kirch (CTSA)	Weimers-kirch (CTSA)	Several locations	Regular school	Several locations	Gilsdorf (CTSA)	Gilsdorf (CTSA)

(All names of participants have been invented.)

In the observational study, $n = 5$ students (four boys, one girl) with ASD participated. The age range of the observed students was between six and 10, with an average age of 7.4 and a standard deviation of 1.5 years. Four of the five students were non-verbal, which means that one was able to speak limited words without a communication system. All students had used Talkii for several months, thus having between one and six months of experience with the device. An overview of the different students' characteristics can be found in table 3.

Table 3: Participants in Observations

Participant:	Age:	Gender:	Characteristics:
Marie	7	Female	- Verbal - 100% integrated in CTSA - own Talkii since 01.2021

John	6	Male	- non-verbal - partially integrated in regular school, partially in CTSA. - own Talkii since 04.2021
Matthew	7	Male	- non-verbal - 100% integrated in CTSA - Will get his Talkii soon
Michel	10	Male	- Non-verbal - 100% in CTSA - no own Talkii yet
Phillip	7	Male	- Non-verbal -100% integrated in a regular school - own Talkii since 05.2021

(All names of participants have been invented.)

All participants were recruited from the CTSA by using a convenience sample, meaning that the sample consists of students with ASD who use Talkii during school as well as teachers and speech therapists who work with these specific students (Carter & Henderson, 2005; Ritchie et al., 2014). All possible participants – teachers, speech-therapists and students with ASD – were contacted through an information letter which presented all the information about participation in this study. Parents had to give consent for the participation of their children in the study.

Data collection

The semi-structured interviews were conducted by using a topic list to guide the interviewee (see Appendix A), including a mix of open and closed questions (Carter & Henderson, 2005). The interviews always started with the interviewee introducing themselves

and then moved on to specific questions about their student's behaviour. One specific question concerned their student's communicative behaviour with Talkii, for example whether they make specific requests to obtain a certain item. Topics of interest were the manipulation of Talkii and the (changed) verbal and social behaviour of the observed students. Here, interviewees were asked to share details about the behaviour of their students before and after they used Talkii. The interviews took no longer than one hour and were audio recorded. Only the main researcher was present at the interview. All interviews were held in Luxembourgish and example citations included in this research were translated to English for understanding.

Observations with students were conducted during several activities, including breakfast, lunch, playtime and speech therapy. The observed activities were selected based on the school setting, including settings in which communication is crucial. Students were observed in their classroom to create a natural setting and were not disturbed by the observation, as the researcher took the role of an assisting teacher (McNaughton Nicholls et al., 2014). All students were observed once in each setting, and data was collected by taking notes about their specific verbal and social behaviour while using Talkii. To structure the field notes for further analysis, the researcher used an observation guide, entailing the five verbal operants defined by Skinner (Johnson et al., 2017) as well as other relevant social behaviour (see Appendix B). Field notes could be directly analysed, meaning that the observed findings were directly put in the specific code categories. Specific observations were then described, for instance whether the student made a request for a desired toy in a specific setting. In order to report findings, frequency tables were created for each setting to present the different types of verbal or social behaviours.

Analysis Plan

For the transcripts of interviews, a qualitative text analysis developed by Kuckartz (2014) was used. This qualitative method suggests creating code categories in order to evaluate the gathered data. Thus, a deductive-inductive category construction approach was used. Within this, it was possible to create categories based on theory, to which the data was assigned. Additionally, unexpected elements in the data, which could not be derived from the designated theories, created new categories (Kuckartz, 2014). Code categories were developed based on theory (deductive gathered category), such as Skinner's theory of verbal behaviour (Johnson et al., 2017) (see Table 1). Codes were then named, for instance 'verbal behaviour', and developed based on empirical data, namely the gathered data from the semi-structured interviews. This technique is called inductive category construction and consists of paraphrasing, generalising and abstracting the original data (Bryman, 2016; Kuckartz, 2014). The coding scheme can be found in Appendix C.

In order to analyse the data gathered from the interviews, the latter were transcribed and read in depth. Then, codes were established. For example, a statement in the transcript that a student requested bread with Nutella was coded as following: The code category for the request would be 'verbal behaviour', adding the code 'request/mand'. In the description of the code, important details about the request could be added, for instance that the student made a request for food. Then, the quotation was added to refer to the example in the transcript. Thus, transcripts were analysed line by line to construct codes (Kuckartz, 2014).

Results

The main aim of this thesis was to examine the (changed) verbal and social behaviour of students with ASD when using Talkii. First, findings about the specific students reported by their teachers and speech therapists are shown, followed by the observational findings for the specific settings.

John

John's teachers reported that he overall uses Talkii to mand to obtain desired items. In addition, even though John has only owned his Talkii for one month, he is already able to use Talkii independently during lunch and breakfast to pick food from a range of different options (i.e., autoclitic). Statements by John's teachers show that they initially thought he was non-verbal but then realised that he is able to produce functional vocal speech. Nevertheless, they are unsure whether this change was influenced by Talkii or indicates that he has severe language difficulties, as his native language varies from the main spoken language in school. Thus, one teacher stated that "she thinks that Talkii actually is very good for his understanding of the Luxembourgish language, as he sees the words with the appropriate pictogram" (Interview Manon, 2021). Regarding his social behaviour, one of his teachers commented that John seems overall happier since he has been communicating with Talkii.

Hmm... I think he seems happier in some way, and you can see in his facial expression that he can tell what he wants. We react faster on his requests, and he laughs a lot. For instance, when he presses on 'cookie' and we give him a cookie, his facial expression changes somehow. I think he is overall happy that he is able to communicate his needs and that we understand him (Interview Mara, 2021).

Marie

Her teachers describe Talkii as "Marie's voice", which was already audible before she used the device but less explicit and functional. For instance, her teacher, Manon, explained that Marie used one sentence for all her requests before she acquired Talkii. In addition, her other teacher, Mara, told me that during playtime, she often requests either verbally or with Talkii to help her bounce on the trampoline. Another kind of speciality that Marie has learned to request with Talkii is the music house. Her speech therapist stated that:

[...] what I find very impressive is that she notices when she needs a timeout and when she wants to enter her tiny house to listen to music. So, the music house, she really asks for this when she feels [...] that she is becoming agitated or annoyed [...]. This self-regulation is there in some way, especially as she has the power to [...] calm down (Interview Linda, 2021).

Findings from the interviews show that Marie's vocal speech has evolved drastically: teachers state that she speaks much more than before and that she has the courage to speak aloud. Besides, she speaks more spontaneously, especially in situations when Talkii is not reachable, and her pronunciation is better. Regarding her changed social behaviour, her teachers and speech therapist reported that Marie experiences fewer crises and less self-injuring behaviour.

Matthew

According to his teachers, Matthew actively uses Talkii, mostly during speech therapy, breakfast and lunch. Both his teachers reported that he seems to be more motivated to mand for a desired item in these settings. His speech therapist confirmed this in the following statement:

Regarding the intuitive behaviour, he seems more eager to [...], more interested in [...] using Talkii, such as what is this and what happens if I click on this button.... Ahh, okay, there is a voice that makes speech output, and then I even get the item I have asked for, okay then I will try again. He is really discovering the functionality of Talkii and shows a lot of interest. This eagerness has made him become more spontaneous in his behaviour [...] (Interview Linda, 2021).

His motivation to mand appears to have increased with Talkii, as his teachers report that he did not request this much with PECS, which might be explained by the fact that Matthew had difficulties seeking attention from his teachers; therefore, they did not always

notice when he wanted something. His teachers stated that this has become a lot easier with Talkii and that Matthew is therefore less frustrated at school.

Michel

Michel's teachers reported that he mostly uses Talkii to mand food during lunch and breakfast. Even though he does not yet have his own Talkii, he can already make multi-step requests. Also, one of his teachers explained that Michel has no difficulties manipulating Talkii, as he uses tablets a lot at home for leisure. His speech therapist stated, and this was confirmed by his teachers, that Michel screams a lot in school when he is frustrated.

However, when he is using Talkii, his speech therapist explained that he is quieter, and she thinks that this might be due to the fact that he is able to communicate more. His teachers confirmed this by explaining that Michel uses Talkii mostly as an extension of his PECS booklet, which he always carries with him. His ability to communicate with Talkii even exceeds his ability to communicate with PECS, as he can even make multi-step requests.

Another observation by Michel's speech therapist was that Talkii might have caused some negative behavioural changes in him.

[...] I have to say that Talkii sometimes freezes, especially when you upload your own photos with a Luxembourgish voice, then the whole application freezes, and this he does not accept at all. When I then say to him, look, it currently does not work... I cannot change it right now. You have to wait for a second. This he ignores completely, and then he starts screaming and crying (Interview Pia, 2021).

Phillip

According to Phillip's teacher, he makes vocalisations similar to beatboxing.

However, his speech therapist argued that this appears to be a stereotypical behaviour that helps to self-regulate and is not caused by Talkii. Besides, she explained that Phillip is able to imitate some words in French (i.e., echoic), even though this is not his mother tongue. His

teacher and speech therapist reported that, during breakfast, playtime and speech therapy, he is able to mand what he wants with Talkii and to choose from a range of different items (i.e., autoclitic). According to his teacher, he can only request in a single step. Regarding his social behaviour, his speech therapist explained that Talkii has had a great impact on his behaviour, especially on his personality.

[...] It is mainly Phillip who I notice is waking up in some way, that one part of his character appears more and more. It brings out what he is able to do and reflects what he might be thinking while he is doing something, what is going on in him. That is revealed in some way through Talkii (Interview Linda, 2021).

Supporting this statement, Phillip's teacher reported that he shows through Talkii who his friends are by clicking several times on their pictures when he sees them.

Alongside the interviews with teachers and speech therapists, students were observed during different activities. It was not possible to observe one student at lunch-time, as this student was integrated in a regular kindergarten and could have lunch at home. No observation during speech therapy was possible for another student, as this student had no speech therapy during the observations were made.

During *breakfast*, students are mostly presented with a variety of types of food, such as bread, butter, jam, etc., from which they can choose what they want to eat. The most frequently observed verbal operant was mand, which was displayed by all participants. For three students, requests were made in a single step, meaning that they directly pressed on the desired food or drink. For instance, John made a single request for two types of food, by pressing first on 'Kiri' and then on 'bread'. The other two students made multi-step requests by formulating a whole sentence with Talkii, such as "Mara, I want bread and salami".

Intraverbal and autoclitic were also observed during breakfast. All five students were able to

choose between different kinds of food, and ask for the one they wanted (i.e., autoclitic). One student responded several times to a question from a teacher (i.e., intraverbal) during breakfast, such as when the teacher asked “Do you want water?” and the student answered by pressing on “Water”. Marie was the only student who showed self-injuring behaviour (she hit her hand against her head) during breakfast, when the requested item was not delivered fast enough. Other types of social behaviour during breakfast were not observed.

Furthermore, *playtime* was observed. Here, four of the five observed students were able to choose a toy (i.e., autoclitic). In this setting, mand was the verbal behaviour most frequently used by all participants. The results show that four students made single-step requests for a desired toy, book or magazine. Besides, two students requested cookies or something to drink; one request was formulated as a single step, by pressing solely on ‘Chocolate Cookie’, and the other as a multi-step: “Mara, I want a cookie”. One student requested ‘Run’ and wanted someone to take her hand and run with her through the classroom. The findings show for this specific student that she can also request verbally, without Talkii, when the device is not within reach. For instance, while bouncing alone on the trampoline, she suddenly stopped and exclaimed “bounce!” to request somebody to jump with her. In addition, this student even verbally imitated (i.e., echoic) the word ‘bounce’, after a teacher had bounced with her on the trampoline and exclaimed “bounce”. These findings were also reported by the student’s teachers, who highlighted that Marie’s vocal speech has increased since the use of Talkii. Next to these types of verbal behaviour, tacts were observed during playtime. A tact was, for instance, observed in Phillip who labelled his peers with their names during a game with Talkii, when the teacher showed him the pictures of the other students in his class. This finding was also highlighted by Phillip’s teacher, who reported that new parts of his personality have appeared since he uses Talkii.

During *speech therapy*, mand was observed in all four participants. Three students made single-step requests to get a desired toy. Nevertheless, the speech therapists tried to guide the students to make a multi-step request several times. One student did similarly mands with two AAC systems: First, he used Talkii to request a toy he wanted to play with. As he did not manage to manipulate the toy on his own, the student used PECS to request 'Help'. Furthermore, three of the four students made intraverbals during the speech therapy, especially when the speech therapist asked them what toy they wanted. For example, the speech therapist asked the student, "What do you want to play?" and the student answered through Talkii, "Knot". Besides, one typical activity, observed in two students, consisted of looking at a storybook which showed animals. Students then had to label each animal they saw with Talkii; thus, when a student saw a cat in the book, they pressed 'Cat' in order to label it. Here, both students needed some visual guidance by pointing to the appropriate animal. Nevertheless, both students were able to label the animals independently after some time. During speech therapy, two students produced some vocal speech. For example, one student started singing a melody while playing with a requested toy, and another made an echoic of a word that the speech therapist had expressed before. Here, the speech therapist said to the student, "Look, there are ducks" and the student imitated "Ducks" verbally. Furthermore, two students were observed in showing undesired social behaviour. One student became frustrated after she had asked for a desired toy that was unfortunately unavailable. Her frustration was visible because she started hitting her hand heavily against her head. The other student became annoyed when he was called upon to make a multi-step request by creating a whole sentence with Talkii. This was visible as he started screaming and running through the classroom.

The fourth and final observed setting was *lunch*. Here, as during breakfast, students were presented with several different types of food. As in the other settings, mand was

observed in all four students who had lunch at school. Two of the four students made a single-step request to obtain their chosen food. For instance, one student requested 'Tomato' and, sometime later, 'Water'. The two other students were already able to make a multi-step request. Furthermore, autoclitic was observed, although only by two students in this setting.

Overall, the manipulation of Talkii was also observed several times. The findings show that all the observed students were able to use the 'delete' button, meaning they were able to delete the requested pictograms in the sentence bar by pressing on a red button displaying a bin icon. Furthermore, three students managed to press the 'play' button to listen again to what they had communicated. Three of the five students were also capable of choosing a category on their own and/or switching between categories. Two switched the device on before using it to communicate, and one even shut it down after having finished speech therapy.

Discussion

The objective of this research was to evaluate a brand-new SGD, Talkii, that has been developed by a Luxembourgish start-up. The main interest lay on the effects this device has on the social and verbal behaviour of students diagnosed with ASD and if it can enhance their communication skills.

Findings from interviews with teachers and speech therapists mainly revealed the changed verbal and social behaviours of their students. Mostly positive behavioural changes were reported: two students were described as happier when communicating with Talkii, as they were understood by other people and able to communicate their needs and desires. This supports the finding that students were also described as less frustrated and experiencing less aggression or self-injuring behaviour in this study. Moreover, this indication is in line with the findings of the literature review conducted by Lorah et al. (2015), in which the researchers state that some studies revealed a decrease in aggression as manding was

acquired and that functional communication training may result in a decrease of other less desirable social behaviours.

Furthermore, the current study revealed an interesting finding that goes beyond the results of previous studies: one student was described by his teachers as experiencing an increased ability in self-regulation by requesting a time-out when upset or agitated. This behaviour was also seen during observations, in which this student requested multiple times during the day to listen to music in a tiny house to calm down, which resulted in less self-injuring behaviour and fewer crises, according to the teachers. Two additional positive behavioural changes were reported by teachers and also observed during different settings which have not been mentioned before in other studies: one student experienced an increase in intuitive behaviour, which appears very unlikely for a student with ASD, as this condition is normally characterised by very rigid behaviour (Lord et al., 2018). This might be explained by the findings of Lorah et al. (2015): that children with ASD are more interested in using a tablet as an SGD to communicate as this is more attractive for them. Another student was described as having experienced a positive behavioural change as new parts of his personality appeared more and more as he was using Talkii. Observations as well as reports from teachers underlined that this student was even able to show who his friends are in school. Such a finding has yet not been reported in other studies. Moreover, one student experienced negative behaviours caused by Talkii: this student was even more frustrated when using Talkii in situations where the device was not working properly. Findings like this have not been discussed in other studies, as mainly positive behavioural changes have been revealed to date (Lorah et al., 2015; van der Meer & Rispoli, 2010).

In addition, observations of students with ASD in different school settings revealed which verbal operants are used in which setting, including frequencies and common patterns. First, the findings of the observations show that, overall, the verbal behaviour mand was used

Commented [WEvd(12): nice!

in every setting, by all observed students. It seems crucial to note that it was also the only type of verbal behaviour observed in every context. The findings of this study are thus in line with other research, as literature reviews by Lorah et al. (2015) and van der Meer and Rispoli (2010) state the same findings. Reflecting on that only a few studies have investigated other verbal operants (Lorah et al., 2015), as the current study has done, one could argue that this is because most children with ASD first learn how to make a request before they use an SGD for other types of communication. This behaviour is also recognised when students with language impairments are taught to use PECS. As PECS protocols are commonly used to teach the use of SGDs (Agius & Vance, 2016), this could explain why participants in this study using Talkii have mostly communicated mands, as they have not yet reached all the different phases of this protocol. Agius and Vance (2016) suggest the same explanation for why most studies only report the acquisition of mand in their findings when evaluating the use of SGDs. Besides, findings from both interviews and observations show that requests were made in a single step and, more rarely, in multi-steps. This finding is in line with the study of Muharib and Alzrayer (2018), who report identical results.

Furthermore, observations revealed that during speech therapy and playtime, all the different types of verbal operants defined by Skinner were shown by students using Talkii. This finding has not yet been made by any other study, as the research gap mainly consisted of not testing all the defined verbal operants proposed by Skinner. Findings about autoclitics and echoics were not made in similar studies investigating the use of SGDs among children with ASD (Lorah et al., 2015, Muharib & Alzrayer; van der Meer & Rispoli, 2010). For speech therapy, this finding seems to be more obvious, as students are, especially in this context, trained to communicate with Talkii. More interesting, however, is the finding about playtime, where students are mostly free to choose their leisure activity. Here, one could argue that the augmented communication is caused by the fact that students could do what

they wanted in this setting, so they were much more motivated to play or ask for a desired toy or cookie. Such findings have not been reported in other studies, possibly due to the fact that such natural settings, in which children can do what they want, have not yet been analysed. Muharib and Alzrayer (2018) report such contexts to be lacking in the findings of their meta-analysis.

Lastly, some findings from both the interviews and observations show an increase in vocal speech in one student and a verbal echoic in another. These findings may hint that Talkii, including the speech output, may trigger vocal speech or vocalisations in students with ASD. Other studies have briefly introduced such findings but also stated that there is a need for more focused studies that specifically study vocal productions as an effect of SGDs (Agius & Vance, 2016; Muharib & Alzrayer, 2018).

To conclude, this study was able to reveal that Talkii is effective in teaching students with ASD a functional verbal behaviour, including all the verbal operants defined by Skinner (Johnson et al., 2017). Furthermore, I was able to identify that Talkii, as an SGD, has a major impact on these students' social behaviour, as most experienced fewer undesired social behaviours, such as aggression, self-injuring behaviour and frustration. Nevertheless, this research has some limitations regarding the methodology and conceptual approaches to evaluating an SGD. Even though the observations and interviews have revealed some interesting findings, it is difficult to make generalisations on the different learned verbal operants, as this study only investigated five students with ASD. Further research should focus on large-scale studies to make generalisations among students possible, in line with Agius and Vance's (2016) suggestions for further research.

The methodology of the study, namely mixed-methods qualitative research, revealed a wider picture of the students' behaviour by reporting both on the used verbal operants and the changed social and verbal behaviours of students with ASD. This was certainly a strength of

this study, as it enabled the research questions to be answered and unexpected findings to be made. However, follow-up sessions should be integrated in future research projects, as single observations, mostly conducted over one day, appear to have been insufficient to draw conclusions concerning a student's verbal behaviour. This is underlined by the fact that the use of Talkii as an SGD should be seen as a learning process, and students with ASD should be given much more time to train on functional verbal behaviour. Last, future research should be conducted on Talkii, as this is the first study investigating it as a commercialised SGD. Here, comparison studies, like those by Achmadi et al. (2014), in which they compare SGDs with other AAC systems, may generate further findings that could enable the producers of Talkii to enhance their device, as some students even experienced negative behavioural changes when using it. In addition, further studies should focus on whether Talkii might also teach functions of language other than those defined by Skinner; the acquisition of a new language could even be analysed. Thus, even more people could benefit from Talkii to enhance their language repertoires.

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Appendix A: Topic list Teachers***Introduction***

- The purpose of this interview
- Informed consent + Thanking for the participation

Background information

1. Name of teacher
2. Years of experience in school and in the CTSA
3. Description of site and the level of their students in class

Talkii

1. How would you describe Talkii in your own words?
2. Since when do you use Talkii in class or since when does any of your students uses Talkii?
3. How is your experience with Talkii as a speech-generating device? Can you tell me how your first experience with Talkii was and how the use of the device has developed until today?

Specific students:

1. How long does Student use Talkii? How did you start using Talkii with her/him?
2. What are the typical things that Student communicates with Talkii?
 - a. Requests?
 - b. Imitations?
 - c. Answers to questions from other communication partner?
 - d. Makes a choice?
3. Has the verbal behaviour of Student changed since she/he uses Talkii?
4. Is Student capable of manipulating Talkii on her/his own?
 - a. Can she/he activate the screen?
 - b. Can she/he switch between categories?
5. Have you experienced a change in Student's social behaviour since she/he uses Talkii?
 - a. Less/more aggressions?
 - b. Less/more crises?
 - c. Less/more focused/concentrated
 - d. Less/more frustrated
 - e. Less/more interested in learning new vocabulary

Closure:

When you could give Talkii a rating from 1-10, what would you say. Explain!

Appendix B: Guide for observations of students with ASD

<u>Student file</u>
Participant code: _____
Age of participant: _____
Gender of participant: _____
Grade of participant: _____
Teacher Code 1: _____
Teacher Code 2: _____
Speech-therapist Code: _____

Description of background:

- How is the daily attitude of the student? (small description of situation)
- Are there any unpredictable changes (change of teachers, new school member, changed routine, etc.)?
- How many other students are in class today?
- What are the characteristics of this student? (non-verbal, stereotypical attitude, etc.)

Context 1-4:

Date of observed context: _____

Pick the observed context!

Playtime	Breakfast	Lunch	Speech-therapy

Observed Behaviours:

Behaviour	Description of behaviour	How many times?
Mand		
Echoic		
Intraverbal		
Tact		
Autoditic		
Vocal Speech		
Manipulation of Talkii		
Other behaviours (decrease/increase in aggression, less frustration, more/less communicative, etc.)		

Important additional notes for context 1:

Appendix C: Coding Scheme for Interviews

Code Category	Code	Description of Code	Example in Material
Deductively gathered from the theoretical framework (Verbal behaviour by Skinner, Social behaviour by Lorah et al.)	Inductively generated from the data (verbal and social (or other) behaviour of students with ASD)	More accurate description of the behaviour or code.	Exact citation from the Data.
Verbal behaviour	Mand	Student makes a request.	Student presses on apple to request an apple.
	Echoic	Student imitates word spoken by Talkii.	After the student has heard the word apple from Talkii, he/she verbally says Apple.
	Intraverbal	Student answers a question from other communication partner.	Teacher asks student what toy he/she wants. Student answers with Talkii "ball"
	Tact	Student labels a word/name.	Student calls his teacher by her name with Talkii.
	Autoclitic	Student makes a choice and requests this/labels this.	The student has to decide between cookies and chips and requests its choice with Talkii, by pressing 'cookies'.
	Vocal Speech	Student speaks without Talkii	Student verbally says the name of the teacher.
	Behavioral Change	Student has a positive/negative vocal behavioral change since the use of Talkii.	The student has a bigger vocabulary since the use of Talkii.
	Others	(No) courage to speak out loud	Student is able to press button and then repeat the word verbally.

Manipulation of Talkii	Activate Talkii independently		Student activates Talkii at the beginning of the observed setting.
	Switch between categories independently		
	Independent use /spontaneous use		
Social Behaviour	Positive behavioral change	Decrease self-injuring behaviour	Student is less frustrated since he/she uses Talkii.
		Decrease frustration	
		Decrease aggression	
	Negative behavioral change	Increase aggression	
		Increase frustration	
		Increase self-injuring behaviour	
	Others	Other people understand what student wants to communicate.	
Others	Talkii	Definition of Talkii	Student makes a request with Talkii during Lunch.
		First use	
		Content	
		Talkii is used at home	
	Setting	Breakfast	
		Lunch	
		Playtime	
	Speech-therapy		