Time processing ability and anxiety in children with autism: evaluation of the effects of music using music timer PLAYtime.

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Abstract: Since estimation of time passage is necessary to create expectations on future events, impairment in time perception observed in subjects with autism expresses difficulties in managing time and handling novelties, causing anxious and repetitive behaviors and social interaction problems. The study aim is to evaluate the potential of using sequences of preferred music to estimate time, and the consequent effects on behavior of children with ASD. Music timer PLAYtime was designed and used during a three weeks testing with the participants, children aged 8 to 12 years with Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS). By using the music timer, children could combine familiar visual feedback (based on time timer) with auditory feedback (favorite songs) to monitor time progress and help estimate duration of different events. The observation demonstrated that the predictability of a sequence of familiar songs combined with visual cues offered benefits to children's attitude towards waiting and ability to autonomously monitor time passage. The findings support studies that hypothesized and empirically investigated the relation between time processing ability (TPA), time management (TM) and autonomy in children with difficulties in TPA. Further research is needed to assess the effects of music sequences in the abstraction of time notion.

Key words: Autism, time processing ability, time perception, music timer, PLAYtime.

1. Introduction:

Historically, time representations has changed together with human development. As Tordjman [18] reminds in her study, mankind always felt the need to control time, creating human constructs such as months, weeks, days, hours, minutes, and designing devices to measure them. In fact, the only way to objectively measure time is to relate past and future to the subjective mental representation of our perception of present. Like Lotze [14] stated, and Gorea [8] quoted him in his research, ''It is not we who are in space [or time], but it is space [or time] which is in us.'', other studies [8, 9, 18] hypothesized internal clocks to make sense of the implications of time relativity on our time perception. Mind clock and body clock work in harmony as long as they have synchronized rhythms, but, since they are strictly dependent one on the other, rhythm disorders on one affect the other functioning.

In the case of autism, few studies [10, 17] suggest that circadian rhythms might be altered, and hypothesize these abnormalities to contribute to or reflect in altered time perception highlighted in autism. According to Boucher [3], timing problems in physiological clock might be related to poor intuitive sense of time observed in

subjects with autism. As reported by Nobre et al. [15] in their study, estimations of time passage are essential to create time expectations, which in turn are useful to optimize our behavior. That is because expectations and predictions allow anticipating events which therefore require less attention, that can be allocated to explore novelties [1, 7]. Consequently, since individuals with autism are oversensitive to changes, they show difficulties in anticipating events and adapt to novel stimuli. Given that planning requires making predictions, and the ability to adapt is needed for changing, subjects with autism show restricted interests, lack in generalization skills and prefer routines and repetitive behaviors to avoid stressful reactions and sense of overstimulation, revealing difficulties in shifting to a new behavior or activity. This aspect of Autism Spectrum Disorders (ASD) proved to be resistant to interventions, and to impede adaption to an unpredictable world, causing social interaction problems [7].

Moreover, it is due to their "endless" physiological continuity, or absence of typical physiological discontinuity, that Tordjman [18] states the hypothesis that children with autism tend to develop anxious behaviors and consequently to create a repeated discontinuity out of continuity, attempting to do everything they can to control time and their perception of time, to be reassured by the illusion to escape physiological continuity. According to her sources [4, 5], beneficial effects can be obtained in children with autism creating a substitute flow, made of sensorial stimuli regularly repeated, so that the subjects can deduce invariants from this discontinuity-continuity system. In fact, they tend to develop what has been defined in the psychological "extreme male brain theory" as a systemizing style [2], showing aptitude for understand highly predictable systems that are governed by clear rules, as reported by Gomot et al. [7]. Furthermore, according to the results achieved by Gunnel Janeslatt et al. [12] in their empirical investigation, time processing ability (TPA) is related to time perception and daily time management (TM), therefore, interventions aimed at improving them contributes to improve time processing ability and autonomy in everyday functioning of children with ASD.

For these reasons the current study hypothesizes that music, which was already proved to help in autism by altering the hormonal state, memory processing, learning, and something called space-time reasoning [13], can represent the replacement of physiological flow mentioned by Tordjman [18], and favorite songs or those more suitable to the specific case become the unconscious internal clock on which to realign subjective time perception. As already described by William James [11] and accordingly to what stated by Tordjman [18], time perception is based on the ability to access memory and to create expectations; therefore the current study aims at investigating if music memory can support difficulties in anticipation, typical of children with ASD, consequently reducing their anxious behaviors and improving their everyday functioning. In addition to this, the children are supposed to know the songs, and, since they can remember them, this means they intuitively relate the specific moment in the song with past and future of the song itself. Therefore, in this scenario, the song is hypothesized to become a new human construct, similarly to minutes, and the invariable sequence of songs would represent a more predictable way to measure time. Moreover, this time unit would allow the child to allocate less attention on time, hence focusing on the action to perform in that time more than on time itself.

2. Materials and methods

2.1 Participants and setting

The participants in this study were three Dutch siblings: two girls aged 8 and 11, and one boy aged 12. Their diagnosis is Pervasive Developmental Disorder Not Otherwise Specified group (PDD-NOS), more specifically

they have been assessed to belong to the high-functioning subgroup, since they all have mild cognitive impairments but present speech problems. Informed consent was obtained from parents. The experimental study took place at children's house for all testing period.

2.2 Experimental design: PLAYtime

A music timer (PLAYtime) was specifically designed for the study, to evaluate the potential of music in children with ASD time processing ability (TPA) and related anxiety and everyday functioning problems. PLAYtime is based on the idea of allowing children with ASD to combine familiar visual feedback (red led bar gradually turning off with passing of time, based on time timer) with auditory feedback (favorite songs played in a predefined sequence) to monitor time progress and help estimate duration of different events.

Figure.1 PLAYtime default initial configuration interface

Figure.2 PLAYtime while playing music

Through an SDcard parents can upload a list of children's favorite songs on PLAYtime. The device has been programmed to play the uploaded songs always in the same sequence, predefined by the parents and the children. It has one speaker, but can also work with headphones plugged in its 3.5 audio jack to allow personal listening. Through specific buttons, parents or children can select the number of minutes (from a minimum of 1 to a maximum of 90) they want the music timer to play, and visualize this number on the front of the device. Then, by pressing the play button, the music starts and the digits are no longer visible in order not to distract children's attention. At the same time, an array of 8 rows of red LEDs turn on. Dividing the time lapse selected into 8 steps of the same duration, the rows gradually turn off one after the other, until the end of the time lapse previously set, to visually help monitoring time passage. The device starts playing the music always from the first song in the list, and proceeds in the sequence until the last LED turns off . From that moment PLAYtime only lets the song currently playing come to the end, and after that it does not start the next one. Of course the music timer is not meant for very specific time measurements, since the last song does not interrupt as soon as all the LEDs are off, but the aim of the whole device is to act in a very predictable way. PLAYtime requires four AA batteries to work, or it can be connected to a computer for power supply.

The music timer design is particularly neat in order not to confuse, and the dimensions of the device allow children with autism to perceive all elements distinctively. The red LEDs have been implemented in the device to provide the children with visual feedback of time progress together with sound one (personal music). Moreover, their design was based on time timer commonly used with children with autism, resulting for them in familiar cues related to time monitoring.

2.3 PLAYtime technical specifications

Figure.3 PLAYtime outside design

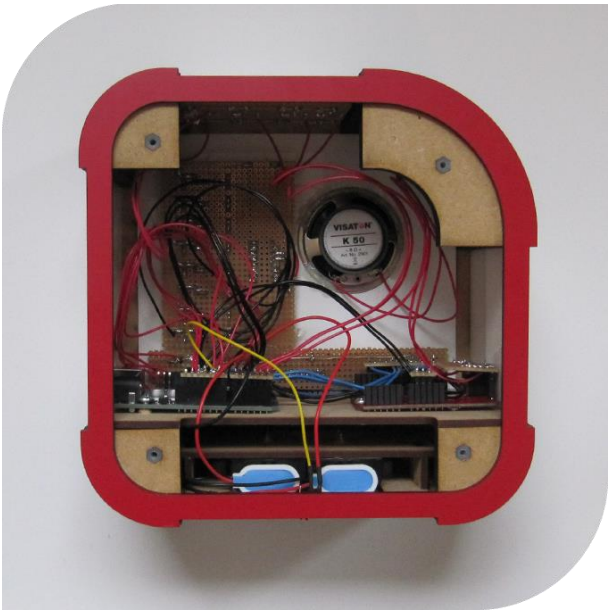

Figure.4 Inside overview of PLAYtime components

The device PLAYtime is controlled using Arduino platform. An ArduinoUNO board is implemented in it together with a MP3 Player Shield. Thanks to the combination of the two, the device can store .MP3 files (the MP3 Player Shield is provided with a slot for an SDcard) and control music playback.

The music timer is provided both with a mono speaker (on the front) and a 3.5 audio jack (on the left side), which can work alternatively thanks to replacement of the original 3.5 audio jack (using which the speaker would have continued to play music also when jack in plug) with a new one that operates as a switch between the speaker and the jack. In this way the device playbacks the audio from the speaker, but when the jack plug is inserted, it switches the output from the speaker to the hearplugs; the user can therefore chose each time how to listen to music, if privately or aloud.

Thanks to the SDcard slot (on the left side), the user can easily upload .MP3 files on PLAYtime: just drag and drop the files on your computer in the main folder of the SDcard and rename the files as *track00#*, numbering them in the order you want the music timer to play them. In this way, the sequence will remain the same, becoming predictable, with time, for children with autism.

In addition to the ON/OFF button (on the bottom) four more buttons with different functions are used to control PLAYtime. They are all on the top of the device and, from left to right, are: minus and plus select/volume buttons, play button, and stop/reset button. The first couple of buttons can be used either to select the number of minutes (from 0 to 90) to play music when turning on the device, or to decrease/increase the volume of the music when it is playing (by default, the volume is set at halfway every time the device is turned on). The play button is used to

start the music playback after having selected the amount of time to play. The function of the stop/reset button is to restart the device in its default configuration (no time selected, no volume adjusted, no songs playing), and, consequently, stop the playback in case the music way playing.

Moreover, two 7-segments digit displays and 8 rows of two red squared LEDs each are used on the front of the device to facilitate interface. The displays are turned on when the music timer is turned on, and, in that moment, they display the digits "00" because no minutes are selected. Using buttons + and – the user can change the time s/he wants the timer to play the music. After having selected the minutes, when the play button is pressed, the music starts playing and the digits turn off, in order not to distract children with information no longer relevant. In the same moment, the 8 rows turn on, meaning the music timer has started and there is still the entire amount of time available. In fact, when the music starts, a timer is activated and controlled in the Arduino code. The timer divides the amount of minutes selected by the user into 8 equal intervals, and turns off one row of LEDs after each interval starting from the top one and proceeding downwards in the sequence. The LEDs gradually turning off are meant for the children to help monitor time progress, providing them with visual feedback of how much time is left. In fact, when all the rows are off, it means that the entire time span previously set is ended, and therefore the device will just finish playing the current song and will not start the next one. This adds predictability to the system, which plays songs always in the same order defined when uploading the songs on the SDcard, and guarantees the children to be able to predict the end of the time span, knowing them the songs and understanding the rules of PLAYtime, which will never stop the playback before the current song is ended. When the time is over (and therefore all the LEDs are turned off) and the song that was being played when the time ended is finished, the device is programmed to reset itself in the default initial configuration, turning on the digits ready to display the new amount of minutes the user wants to select.

PLAYtime was designed to allow its usage either with four AA batteries (slot on the bottom) or connected to a computer for power supply. The same connection (on the right side) can be used to re-upload the Arduino code on the board in case any change is needed (e.g. it may be desired to set a maximum amount of minutes that can be selected different from the current, which is 90 minutes). Moreover, if any technical problem occurs, all the electronics is accessible by unscrewing the back side of the device.

2.4 Experimental procedure

The music timer PLAYtime has been tested by the participants in a three weeks period of time, during which the device has been used on a regular basis with all three children together at least once a day.

Qualitative data were collected to evaluate the research question, that is to which extent favorite songs, together with familiar visual cues, can help children with autism to monitor passing of time, to predict the end of a specific time lapse and to reduce anxious behaviors while waiting for an event.

The data collection was planned to be unobtrusive due to the oversensitivity to changes typical of children with autism. For this reason, similarly to the method applied by Janeslatt et al. [12], an indirect observation was considered to be the most suitable in this specific case. Moreover, it allowed testing the effects of the music timer in various personal situations without interfering with private daily life. The mother of the participants was first trained on PLAYtime functioning and informed on her role in the test. She was required to report the functioning to the children, set the timer together with them, observe their behavior before and while using it, and take notes on anything she considered relevant, also compared to past experiences of the specific child, together with some

aspects she was asked to observe. The outline of these specific aspects she was provided with derived from Gorea [8] review of the factors that might affect the perception of duration, and consisted of: novelty, attention, action, task difficulty and emotion. Moreover she was asked to test the effect of PLAYtime in two different kinds of situation: in the first case the device was used by the participants to monitor time while performing an activity, while in the second case the device was used to monitor time left to wait before an event occurred. In the first case, the aim was to evaluate the ability of the child to focus on an activity while monitoring time with music, and to note differences from child's typical behavior without the music timer, while, in the second case, the observer's attention was towards anxious behaviors derived from waiting. In both kinds of situation she was asked to note the kind of activity the child was required to perform or the kind of activity performed while waiting, the name of the child who was required to perform that activity or to wait, the child's familiarity with the kind of activity required or the kind of event s/he has to wait for, the mood of the child before starting the activity and while performing it or before requiring him/her to wait and while waiting, the duration of the activity or waiting time and consequently of the time lapse set on the music timer, the child's ability to organize the time set, the ability to perform the task while the music timer is playing, the attention directed to PLAYtime (and, more specifically, to visual feedback or to auditory feedback), the ability to predict the end of the time set and therefore to stop the activity or waiting.

During the three weeks of testing, a continuous communication between the observer (mother of the participants) and the experimenter (CG) helped monitoring the progress, and, at the end of the testing period, a meeting was planned to discuss one-to-one the collected data by the mother. The interview was aimed at guiding the interviewee thanks to the observation key point schedule, on the other hand maintaining the richness of qualitative data collection.

3. Results

The music timer has been used by all three participants, together or separately, every time for 10 to 30 minutes. Without any requirement of usage frequency, they used it every day more than once during the three weeks testing period. As reported by the observer, all three children loved it, and it proved to be fun to use and intuitive in its functioning. In fact, all three children perfectly understood its rules, being provided with little information: they were just told that when the music is off time is ended. The observer hypothesized that, since they were already used to time timer, the familiar cues present on PLAYtime were enough for the children to autonomously make logical connections between LEDs functioning and music, understanding that as soon as all the LEDs are off the music timer will not start the next song but just finishes the one currently playing.

In addition to this, even if it was not required to them, the oldest children (aged 11 and 12) learnt how to set the timer without explanations, and showed proactive behavior willing to set it themselves. Initially they were explicitly told to use it, the days after they proactively decided to use it whenever they were told to wait or carry on an activity for a period of time. In both these situations the observer noticed that the participants' focus was not on the timer itself, apart from sporadic glances at the LEDs. For the rest of the time they allocated their attention to the activity required, sometimes singing the songs.

The participants used the music timer for waiting for dinner or for a family member to come home, or for monitoring time set for specific activities such as having a shower or playing. In all situations the device was used

with the speaker and not with the headphones because it played for more than one child or while the child was involved in another activity.

The observer reported different approaches to feedbacks provided by the device. The oldest participants acted as a team in monitoring time passage, the girl monitoring LEDs and warning the boy when they were all off and therefore "it is almost time", the boy mainly paying attention to music and warning the girl when also the last song ended and therefore time was finished. On the other hand, the youngest sibling preferred to be in control of everything, monitoring autonomously visual feedback and sound. For all three participants the observer stated that the combination of the two kinds of feedback was the most suitable design choice, because they all have been diagnosed to have abnormalities in perception sensorial levels (visual above average and auditory below average), but they score at average rate when the two senses are stimulated simultaneously.

Furthermore, already from the first time the device was used, the observer noticed that the children changed their habitual anxious behavior in a more relaxed one. In fact, the girl aged 11 usually stared at the clock, being the only one who can read the analog clock, while her siblings tended to keep asking parents how much time was passed or was left. On the other hand, the qualitative data collected through observation demonstrated that during the testing they proved to autonomously monitor time passage and to be more calm when waiting, taking PLAYtime with them whenever they needed to monitor time passage and demonstrating abilities in predicting the end of time lapses thanks to auditory and visual cues.

4. Discussion

This study demonstrated that time processing abilities of children with autism can be improved by interventions aimed at improving time management, supporting the empirical investigation carried out by Janeslatt et al. [12]. In fact, by using the music timer, the participants were seen to clearly benefit from the predictability of the functioning of the device and showed improved time perception. The children also showed reduced anxiety levels, as observed by the mother, which allowed higher autonomy of the children. Moreover, the device proved to be very intuitive to use for all participants, and this fact allowed them to use it autonomously, rewarding them and shortening the perceived duration of waiting due to its predictability and the intentionality of the children to produce the event, in accordance with what stated by Tordjman [18]. In addition to this, auditory feedbacks enabled the participants to allocate less attention to the timer itself, therefore shifting their focus from time passing to the activity they performed in the meantime. As a result, overstimulation was avoided, waiting was perceived to be shorter [6, 8, 18], children's attitude became more relaxed, and repetitive behaviors disappeared. The need to control time was satisfied, showing abilities to understand time progress and anticipate the end of time spans, and their typical symptoms of anxiety were not observed.

The conclusions drawn must be related to the limitations of the study. The homogeneity of the participants might be considered as a limitation. The children aged between 8 and 12, therefore no information could be derived from this research on younger or older children with ASD. Moreover, the three participants were siblings. Hence, it is possible that some specific dynamics influenced the group members. Since they all have the same familiar background and a similar education accordingly to their personal needs, in some circumstances this might result in similar mindset. Also the diagnosis of the three participants was comparable: they all have been classified as high functioning autism. Even though this subgroup of PDD-NOS includes a wide range of variability,

nevertheless all three participants shared some traits. In a future study PLAYtime should be tested with more children with various conditions. Another fact that might have influenced the result was the single observer. Even though she had the familiarity and expertise needed for interpreting the children behaviors, the qualitative data collection derived from only one point of view and interpretation. Therefore further studies might compare the results achieved with this investigation to those achievable with multiple observers. During the testing period, activities that require low attention level were performed while PLAYtime was playing, and in this scenario music proved to be a valuable mean to improve TPA without distracting. Opportunities for future developments might lie in evaluating the relation between specific kinds of music, context of use and the difficulty level of activities children with ASD are able to perform while monitoring time through music. In addition to this, the results of the qualitative research demonstrated that PLAYtime music timer could immediately affect positively participants' attitude, autonomy and ability to monitor time progress. Further investigation is needed to evaluate the long term influence of the combination of auditory and visual feedback, together with the attention level towards one or the other sensorial stimulus. Longer studies might investigate effects of PLAYtime on abstracting time notion and creating synchronization between body and mind clock in order to intuitively perceive time passage.

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