Acceptance and potential clinical added value of biocueing in forensic psychiatric patients with autism spectrum disorder and/or intellectual disability

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A B S T R A C T

Autism spectrum disorder (ASD) and intellectual disability (ID) are prevalent in forensic psychiatric samples. People with ASD and/or ID often experience difficulties in emotion processing which can lead to aggressive or self-harming behavior. The use of biocueing (using wearable technology to constantly monitor and provide feedback on bodily changes) shows promise for improving emotion processing and, thus, potentially reducing aggressive behavior in this population. Both qualitative and quantitative methods were used to examine the feasibility and acceptance of Sense-IT, a biocueing application, in a sample of forensic psychiatric patients with ASD and/or ID and their forensic psychiatric nurses. To our knowledge, the current study is the first to examine first-person experiences with biocueing in forensic psychiatric patients with ASD and/or ID. Results show that, in general, participants experienced the biocueing application as positive and are willing to use biocueing. This is an important finding since forensic patients are often unmotivated to engage with therapeutic techniques. An exploration of trends in aggression and self-harm prior to and during the use of biocueing showed no significant changes. Future research should focus on the way biocueing can be implemented in clinical practice.

1. Introduction

Autism spectrum disorder (ASD) and intellectual disability (ID) are prevalent in forensic psychiatric populations (King and Murphy, 2014; Fogden et al., 2016). ASD is characterized by persistent deficits in social communication and restricted, repetitive patterns of behavior, interests, or activities (DSM-5; APA, 2013). ID includes both intellectual and adaptive functioning deficits in conceptual, social, and practical domains (APA, 2013). Both individuals with ASD and ID demonstrate impairments in processing their own emotional responses (Bird and Cook, 2013; Hill et al., 2004; Janssen et al., 2002). Emotion processing includes both the recognition of emotions and the regulation of emotions (Kret and Ploeger, 2015). These difficulties in emotion processing are associated with various forms of challenging behavior, including self-harm and aggressive behaviors (Cohen et al., 2011; Crocker et al., 2006; Janssen et al., 2002; Mazurek et al., 2013). Currently, there is a lack of evidence-based tools to improve emotion processing in people with ASD and/or ID (Binnie and Blainey, 2013; Kan et al., 2013; Singh et al., 2011); this is a major unmet clinical need.The use of technology that measures physiological parameters (e.g. heart rate) has shown promise for improving emotion processing and, thus, potentially reducing aggressive behavior and self-harm (De Looff et al., 2019; Gray et al., 2019; Kuijpers et al., 2012; Ter Harmsel et al., 2021A; Torrado et al., 2016). Ambulatory, constant monitoring and feedback on bodily changes through wearable biocueing could provide individuals with an objective tool to signal deviating arousal levels, real-time in everyday life, allowing for just-in-time behavioral support (Ter Harmsel et al., 2021A). Studies in laboratory setting showed that wearable devices can be used to discriminate physiological states associated with rest from those associated with emotional stress in individuals with ASD (Masino et al., 2019). Results furthermore suggested that aggression to others can be predicted by heart rate measured by biosensors in naturalistic observation studies of youth with autism (Goodwin et al., 2019; Imbiriba et al., 2020) and adult inpatients (De Looff et al., 2019). Also, a pilot study showed that real-time biofeedback may improve emotional self-regulation in children with ASD (Torrado et al., 2017). Altogether, the use of wearable technology shows promise to timely recognize aggressive outbursts and to improve emotion processing of patients with

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ASD and ID.

Yet, however promising, biocueing can only be effective when people are willing to use it. Many mental health applications are developed with little regard to the specific characteristics and needs of its target users (Derks et al., 2017). Many users stopped using a mental health application after only two weeks, especially when their preferences were not met (Torous et al., 2019). It is therefore important to include the input of clinicians and patients while designing a new mental health application, especially when designing an intervention for forensic patients who are regarded as a complex and highly unmotivated population (Derks et al., 2017; Kip et al., 2019; Torous et al., 2019). Furthermore, studies showed that patients with ASD find it important that wearable technology is invisible and does not attract unwanted attention from others (Sharmin et al., 2018; Taj-Eldin et al., 2018). However, scientific records of first-person experiences related to biocueing technology is scarce (Ter Harmsel et al., 2021A). To our knowledge this was the first study examining first-person experiences with biocueing of forensic psychiatric inpatients with ASD and/or ID.

The primary goal of the current study was to examine the feasibility and acceptance of Sense-IT, a biocueing application (Derks et al., 2017; 2019), in forensic psychiatric patients with ASD and/or ID. A secondary aim was to explore trends in aggression and self-harm over a period of time prior to and during the use of biocueing.

2. Methods

A convergent mixed-method design was applied to examine the research questions. A convergent mixed-method design involves the collection of both qualitative and quantitative data in order to examine a research question (Creswell and Creswell, 2017). Qualitative data, collected via semi-structured interviews, were the main source of data to examine the acceptance and feasibility of Sense-IT as it provided insight in the participants' experience of the intervention. Additionally, quantitative data were collected using System Usability Scale (SUS) and Client Satisfaction Questionnaire (CSQ-8) in order to confirm findings from the qualitative data. For the second research question, quantitative Social Dysfunction and Aggression Scale-11 (SDAS) data were collected in order to explore trends in aggressive and self-harming behavior over time. A mixed-method was chosen in order to obtain a stronger understanding of the topic (Creswell and Creswell, 2017). Quantitative and qualitative data were integrated using a side-by-side comparison (Creswell and Creswell, 2017).

2.1. Participants

The sample consisted of 15 patients with ASD and/or ID admitted to a medium secure forensic psychiatric hospital with a criminal charge. The majority of the sample was male (80 percent, $n = 12$) and the mean age was 37.5 years (SD = 10.98; range 26–63 years). Inclusion criteria were a diagnosis of ASD and/or ID according DSM-5 criteria and being mentally competent. Exclusion criteria included the use of beta-blockers or not being able to read, speak or write the Dutch language. In the current sample, 7 patients were diagnosed with ASD, 6 patients were diagnosed with ID, and 2 patients were diagnosed with both ASD and ID. Comorbid psychiatric disorders were prevalent in the sample, including substance-related disorders (66.7 percent), schizophrenia and other psychotic disorders (53.3 percent), personality disorders (26.7 percent), trauma and stressor-related disorders (20 percent), ADHD (13.3 percent), depressive disorder (6.7 percent) and paraphilic disorders (6.7 percent). With regard to the history of violence, 66.7 percent of the sample was (previously) convicted for violent crime, 46.7 percent was (previously) convicted for property crime (with or without violence) and 13.3 percent was (previously) convicted for sexual offenses.

Also, 6 forensic psychiatric nurses who were responsible for every day care at the ward were included. The majority of this sample was female (83.3 percent, $n = 5$) and the mean age was 28 years (SD = 6.2; range 24–39 years).

2.2. Intervention

The Sense-IT application was designed through an extensive study using a 'Users Experience Design' approach in which patients with borderline personality disorder and their therapists were involved (Derks et al., 2017). Sense-IT is a biocueing application with two sides. The smartwatch side of the intervention displays heart rate as measured by the smartwatch internal sensors, and then transformed to a simplified scale with levels from -3 to $+5$. At first use, an individual mean baseline heart rate and standard deviation were determined based on a measurement of approximately 30 min while the participant does his daily activities. Then a threshold criterion can be established for informing users of rising and falling heart rates (i.e. a change of 0.5, 1 or 2 times the standard deviation). The user was visually and (optionally) tactilely informed of this change via the smartwatch. The smartwatch application served as an additional monitor (and possible post hoc reflection on trends over time) to become aware of the change in heart rate. An on-board accelerometer together with Google Android built in algorithms classified the current activity of the wearer into six categories: in vehicle, on bicycle, on foot, running, still, walking. Subsequently, the user can be notified of substantial heart range changes during little or mild activity only (e.g. in vehicle, on foot, still and walking). The smartphone side of the app provided insight in previous measures and served as a diary that can be used to make notes about the change in physiological arousal. The hardware used was the commercial smartwatch Ticwatch E in combination with a Nokia 2, Android 7.1 smartphone.

2.3. Materials

A semi-structured interview was used to qualitatively examine participants' experiences with the Sense-IT application during the study period, including experienced obstacles and suggestions for improving Sense-IT. Sample questions were: 'How was your overall experience with Sense-IT?', 'Can you come up with situations (which did not take place during the study) in which you would like to use Sense-IT? ', 'What thoughts did you have when Sense-IT (did not) correspond to your feelings?' and 'What is your opinion on the visual feedback provided by Sense-IT?'. The same interview was used for both patients and nurses. With regard to the nurses some questions were slightly rephrased. For instance, we asked the nurses "In your opinion, in which situations did Sense-IT help the patient" instead of "In which situations did Sense-IT help you?".

2.3.1. Client satisfaction questionnaire (CSQ-8)

The CSQ-8 was used to quantitatively examine the participants' experience with Sense-IT. The CSQ-8 (Attkisson and Zwick, 1982) is the short version of the original CSQ-18 (Larsen et al., 1979) and consists of 8 items used to evaluate consumer satisfaction with health services (Sense-IT in this case). The short version of the CSQ was chosen, since it performs as well as the CSQ-18 (Attkisson and Zwick, 1982). Items were scored on a four-point Likert scale, with higher scores indicating higher satisfaction. Total CSQ-8 scores can be subdivided in four categories: poor (8–13); fair (14–19); good (20–25) and excellent (26–32; Smith et al., 2014). The CSQ-8 showed high internal consistency (Cronbach's α = 0.91; De Brey, 1983). A sample question is: 'To what extent did Sense-IT meet your wishes?'.

2.3.2. System usability scale (SUS)

The SUS (Brooke, 1996) is a balanced 10-item-scale compromised of positively and negatively worded items that are scored on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The negatively worded items were coded so that high scores indicated a high quality of system usability. SUS scores have a range of 0 to 100. The

quality of the system usability is considered 'low marginal' with a score above 50, 'high marginal' with a score above 62 and 'passable' with a score above 70 (Bangor et al., 2008). The SUS showed high reliability in a sample of 2324 surveys (Cronbach's $\alpha = 0.91$; Bangor et al., 2008). The SUS was translated to Dutch in a previous study (Jansen-Kosterink et al., 2012). According to the original author of the SUS, the Dutch translated version had similar internal reliability to the original English version (Brooke, 2013). A sample question is: 'I need the help of a technical person in order to be able to use Sense-IT'.

2.3.3. Social dysfunction and aggression scale-11 (SDAS)

Trends in aggression and self-harm were quantitatively explored using the SDAS-11 (Wistedt et al., 1990). The SDAS-11 consists of 9 items concerning overt aggression and hostility and 2 items concerning self-harm. Items were scored on a five-point scale from zero (no incidents) to four (very severe incidents), using a detailed manual in which scores are clarified. The Dutch version of the SDAS-11 has shown good convergent validity and moderate interrater reliability (Kobes et al., 2012).

2.4. Procedure

The study has been approved by the medical ethical committee of Twente, Enschede (number: NL 65,285.044.18) and was registered in the Dutch Trial Register (NTR, NL7158).

For the selection of participants, all inpatients from four different wards from a forensic inpatient hospital were approached as potential participants; they were informed on the aim and purpose of the study and received a demonstration of Sense-IT. Eligible patients signed the informed consent. In- and exclusion criteria were checked with the responsible clinician after the patient signed informed consent and gave permission to do so.

SDAS was scored daily as part of routine clinical assessment by forensic psychiatric nurses. For the purpose of the study, SDAS-data collected during the study period with Sense-IT were analyzed, as well as data collected in the 30 days prior to the start of the study period as an extensive baseline level of aggression and self-harm.

At the start of the study period with Sense-IT, participants were instructed on the use of Sense-IT. The study period started with a 'set-up day' in which the baseline measurement took place. The following day, participants had a 'test-day' to experience the different types (visual or tactile) of feedback from the smartwatch and the different levels of thresholds (standard deviations from the baseline). After the most comfortable feedback and threshold were determined, and baseline heart rate measurements were performed, participants wore the Sense-IT smartwatch during two weeks. Participants were instructed to wear Sense-IT all day long: from getting up in the morning to going to bed in the evening. Participants were contacted repeatedly by the first author to check whether there was a need for additional support.

The day after the 2-week study period finished, participants were interviewed on their experiences with Sense-IT. The forensic psychiatric nurses were also interviewed on their experiences with Sense-IT. Those participants, only patients not staff, who complete the interviews received a compensation in the form of vouchers worth €20,-, regardless of the actual use of the Sense-IT smartwatch and smartphone.

2.5. Statistical analyses

In order to examine the feasibility and acceptance of Sense-IT the mean score and standard deviation were computed for SUS and CSQ-8 using IBM SPSS Statistics (version 25). For the qualitative analyses, semi-structured interviews were transcribed and provided with meaningful units by the first author. Meaningful units consist of words or sentences containing information related to the research questions. Next, a coding scheme was proposed by the first author with four main themes: experiences, added value, obstacles and improvements (see

Table 1
Coding scheme of the semi-structured interviews.

Theme	Theme description
Experiences	All answers that refer to the way a participant experienced the use of Sense-IT. Example: "I had a good experience with Sense-IT … I found it interesting to use it"
Added value	All answers that refer to the clinical added value of Sense-IT as mentioned by participants. Example: "I would recommend Sense-IT to myself. It is good to become more aware of feeling tense or that you are worried. Sense-IT makes aware; then you can put a stop to it. It is no fun, but it is good"
Obstacles	All answers that refer to aspects of Sense-IT and the technology in general that did not work properly according to the participant Example: "The watch sometimes loses connection after you have been away from the phone, it can take a long time for the connection to recover. It does help to turn the app on and off."
Improvements	All answers that refer to aspects of Sense-IT that need to be improved and suggestions for extended functions of Sense-IT. Example: "The battery life of the watch needs to be improved, now you have to charge too often"

Table 1), these themes were discussed with the second author (FC) and were agreed on. At first, the first author also assigned subcodes, but after consideration with the other authors (FC and MLN), we decided that those subcodes did not provide additional relevance in answering the research questions and decided not to use the subcodes. Afterwards, all interviews were coded by the first author (RB). Two interviews were separately coded by a second coder who was not directly involved with the participants (MLN). The authors decided to double-code only these two interviews, because the selected interviews were by far the most extensive and covered all of the themes. Based on those interview the interrater-reliability was computed using Cohen's kappa, showing a substantial interrater-reliability ($\kappa = 0.79$; $p < .01$). The same coding scheme was used to code interviews with both patients and nurses. Accordingly, we analyzed all interviews together. When comments were only given by either patients or nurses, this is indicated in the Results.

In order to examine the potential clinical (added) value of Sense-IT, SDAS data were used. First, we graphed SDAS data for each participant. To gain insight in the trend, level and stability of the data, a visual analysis was conducted (Lane and Gast, 2013). Furthermore, we used IBM Statistics version 25 to compute estimated marginal means for SDAS scores per participant, per Time Point (day 1, 2, 52) and per Measurement (pre or during the use of Sense-IT). These data were plotted to gain insight in the trend, level and stability of the data. Finally, we fitted a linear mixed model using an autoregressive covariance structure (AR1), with SDAS scores as outcome variable and Time Point and Measurement as predictor.

3. Results

3.1. Qualitative results

3.1.1. Experiences

The first theme concerned the experience of participants with Sense-IT. The majority of participants (17/21) reported positive experiences with Sense-IT. Some participants (7/21) cited that Sense-IT had no added value for them, mostly because they reported that they had no problem regulating and recognizing their emotions. Two other participants cited that they experienced Sense-IT as demanding.

Furthermore, participants (7/21) mentioned the importance of being able to personalize settings to the individual patient, for example: "At first, the watch vibrated often, which I found annoying. Later, the watch only vibrated with high levels of tension, which was fine. It's nice that this setting could be changed.".

3.1.2. Added value

Participants were asked questions on the added value of Sense-IT. The majority of participants (17/21) cited that Sense-IT helped to recognize stress and calmness. Sense-IT provided insight into which activities they found calming and which activities caused stress. Also, participants reported that Sense-IT gave them a confirmation of what they thought they were feeling: "Sometimes it [Sense-IT] helped to recognize stress: I often had a higher heart rate before activities or when someone is walking behind me, which I find annoying. I already knew this a little bit, but it has started to stand out.".

Also, participants were asked whether they would recommend Sense-IT to other patients and if so to which patients. The majority (18/21) cited that they would recommend the use of Sense-IT. Some of them (12/18) explicitly mentioned that they would recommend Sense-IT for patients who experience high level of stress; others (6/18) would recommend Sense-IT for other reasons, such as "It [Sense-IT] is good for everyone to experience and consider "what am I feeling?".

3.1.3. Obstacles

Participants were asked what limitations of Sense-IT they experienced during the study period. Participants (7/21) mentioned technical issues of Sense-IT as an obstacle. They mainly mentioned that sometimes the Bluetooth connection between smartwatch and smartphone was interrupted, causing Sense-IT not to work properly. Also, participants (9/21) mentioned that the current battery life of the smartwatch was poor. This was considered a major obstacle since participants had to charge the smartwatch twice a day in order to be able to use Sense-IT.

Another obstacle mentioned throughout the interviews was that participants (12/21) doubted the accuracy of the feedback provided by Sense-IT. This follows the experience of participants that at times Sense-IT mentioned a rise in heart rate when they did not experience stress themselves, and vice versa: "I think tension in my head goes unnoticed. A few times I had stress or mild irritation and I got one dot at most.". Participants explained this as an obstacle of Sense-IT as they interpreted the absence of a high heart rate measured by Sense-IT as a statement that they would not experience psychological stress.

Furthermore, two participants cited that they found the vibrating signal of Sense-IT disturbing while they were resting: "While resting, I found the vibration very irritating. I would rather have the watch to light up when something changed. During activities I did like the vibration function, it made me aware of what is happening.". Other obstacles in the use of Sense-IT that were mentioned by individual participants were: the fact that feedback provided by Sense-IT was visible for others caused discomfort, physical activities were not always recognized correctly by Sense-IT and the size and weight of the smartwatch.

3.1.4. Improvements

Participants were asked for suggestions to improve different aspects of Sense-IT. Participants (6/21) mentioned that the battery life of the smartwatch needs to be improved in order to be able to fully use Sense-IT. Another theme that occurred throughout the interviews was the visual feedback provided by Sense-IT. Although most participants (20/21) experienced the visual feedback provided by Sense-IT as clear, additional forms of visual feedback were suggested, such as (traffic light) colors, graphs and thermometers in addition to the current options. Altogether, there seemed to be a need for several options in order to be able to personalize the feedback provided by Sense-IT.

Another important suggestion for improvement was the possibility to link more functions to Sense-it. Several participants (3/21) mentioned that they would like Sense-IT to both signal their stress, and also provide a calming intervention following such a biocue. Also, participants (5/21) mentioned that they would like to be able to use other health measurements that smartwatches can take: "I would prefer to use Sense-IT when you can use multiple functions on the smartwatch, such as the pedometer and sleep and health monitoring.".

All nurses mentioned the need for additional guidance for participating patients; they doubted whether patients fully understood the use of (feedback provided by) Sense-IT. Also, 4 out of 6 nurses mentioned that they would like to gain insight in Sense-IT data: "It would also be nice if nursing staff could gain insight into the heart rate of a patient through an app or online portal. For example, I would like to receive a notification when someone has 4 or 5 dots, especially if they appear calm.".

Other suggestions for improvement that were mentioned by individual participants were: a longer baseline measurement, a notification when Sense-IT loses Bluetooth connection and improved recognition of physical activities.

3.2. Quantitative results

Descriptive analyses of CSQ-8 and SUS showed a mean CSQ-8 score of 19.78 (SD = 1.77), $N = 18$) and a mean SUS score of 76.39 (SD = 9.82), $N = 18$). The mean CSQ-8 score represents a fair satisfaction score (Smith et al., 2014). The mean SUS score was above the passable threshold (>70), suggesting that participants considered Sense-IT good quality with respect to its usability.

3.2.1. SDAS

Visual analysis of SDAS scores of individual patients showed that overall SDAS scores were low. Total SDAS scores per day ranged from 0 to 34. The estimated marginal mean SDAS scores per participant showed that few patients showed disruptive behavior during the total study period. A plot of SDAS scores over time showed a slight decline in SDAS scores. However, when a distinction was made between SDAS scores pre-intervention and SDAS score during the use of Sense-IT, this decline was no longer visible, see Fig. 1a. Altogether, based on visual analysis and estimated marginal mean SDAS scores, it appeared that most participants showed little to no change in SDAS scores after the introduction of Sense-IT, and few showed a decline or incline in SDAS scores after the introduction of Sense-IT, see Fig. 1b. Fig. 2 shows the SDAS trend lines of two individual participants with the biggest change in SDAS scores. These participants were selected as an illustrative example to show two different trend lines: the first participant (SI-12) showed a decline in SDAS scores during the use of Sense-IT, whereas the second participant (SI-9) showed an incline in SDAS scores during the use of Sense-IT. The difference in trend lines could not be explained by the qualitative data.

Finally, linear mixed models showed that there was no significant difference in estimated marginal mean SDAS scores between pre-intervention measurements and measurement during the use of Sense-IT (F (1, 182.53) = 0.01, $p = .92$).

4. Discussion

The main goal of this study was to examine the feasibility and acceptance of a biocueing application in a sample of forensic patients with ASD and/or ID and their nurses. Qualitative results cautiously indicate that, overall, both patients and staff experienced the biocueing application as positive and were willing to use a biocueing application in clinical practice. Quantitative results showed adequate usability scores and fair satisfaction scores. The results are is in line with a previous study indicating a positive attitude and similar usability outcomes for forensic outpatients towards the use of biocueing (Ter Harmsel et al., 2021B). In addition, the majority of the sample stated that the biocueing application may help them recognizing changes in arousal (both stress and calmness). These findings are promising because of the complex and highly unmotivated nature of forensic psychiatric patients with respect to many existing therapeutic techniques (Kip et al., 2019), especially given the fact that in the current study a prototype of Sense-IT was used.

The current findings provide insight in the specific needs of patients with ASD and/or ID in using a biocueing application. For example, some patients with ASD experienced the tactile (vibrating) signal provided by

a

Estimated marginal mean SDAS scores time × measurement

b
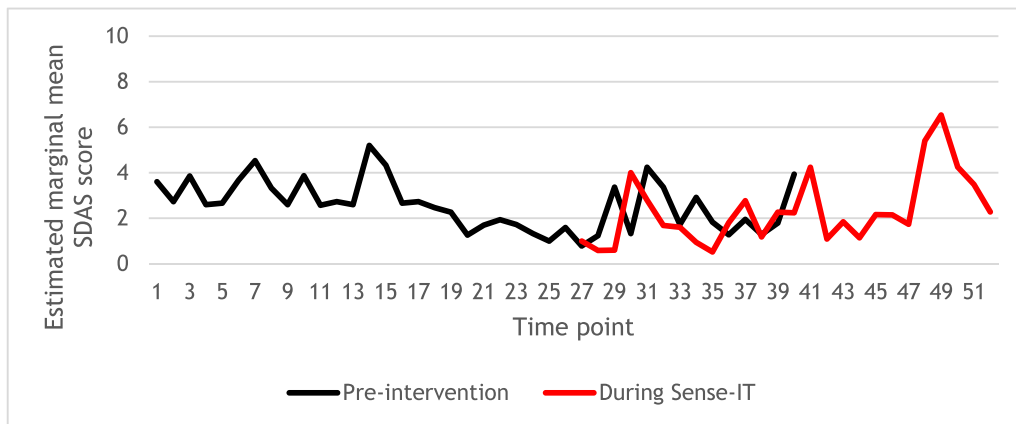
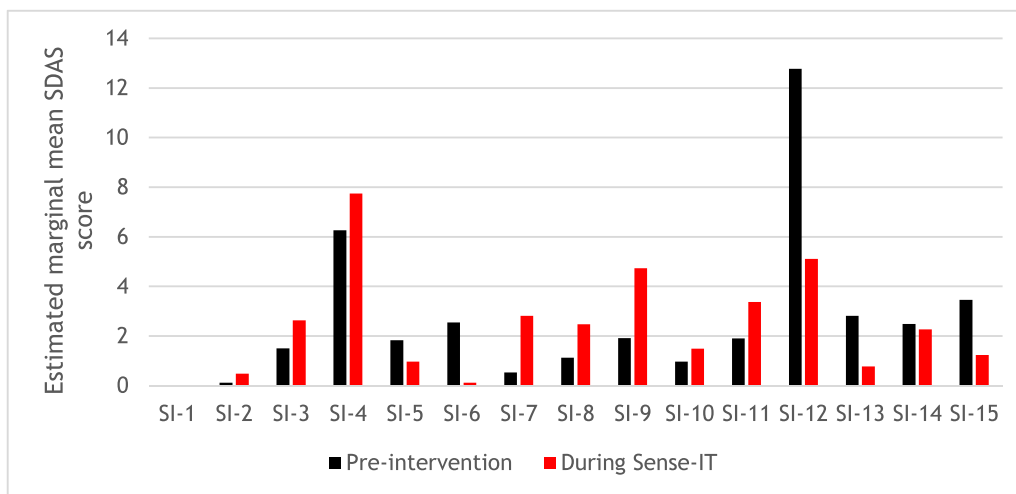*Estimated marginal mean SDAS scores participant × measurement*

Fig. 1. a Estimated marginal mean SDAS scores time × measurement Figure 1b.Estimated marginal mean SDAS scores participant × measurement.

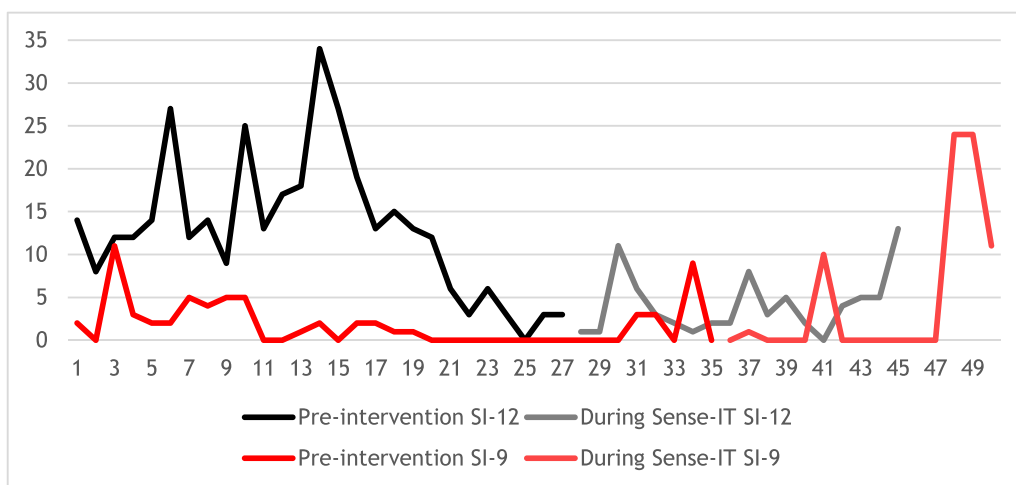*Total SDAS scores of two participants*

Fig. 2. Total SDAS scores of two participants.

the smartwatch as disturbing. This is in line with the fact that people with ASD often experience sensory hypersensitivity (APA, 2013). For these patients it was necessary to reduce the vibrating signals. However, other participants mentioned that they prefer a clear tactile notification of change in heart rate. This example shows the importance of being able to personalize feedback settings in order to suit the specific needs of an individual.

Furthermore, participants mentioned that the biocueing application did not always respond to their subjective experiences. This can be explained as a need for a more detailed explanation of biocueing. The biocueing application uses heart rate to provide feedback, while also measuring activity, which allows it to cue substantial heart rate increases in low physical activity situations. However, heart rate is limited in recognizing psychological stress. The added value of the current implementation of biocueing is that it can point out any large changes in heart rate without an increase in physical activity. Those moments are of interest, because they can indicate psychological stress (Ter Harmsel et al., 2021A). Biocueing can however not provide a perfect recognition of subjectively experienced stress nor can it uniquely identify emotional states (Siegel et al., 2018). During the current study it appeared that some participants did expect this and were not feeling validated when the biocueing application did not give a signal when they subjectively experienced stress. It is thus important to provide a more detailed explanation that is in line with characteristics of patients with ASD and/or ID in order to manage the user's expectations.

A secondary goal of the current study was to examine trends in aggression and self-harm prior to and during the use of a biocueing application. The current results did not show significant trends in aggression or self-harm. An explanation for this finding is that it appeared that overall levels of aggression and self-harm were low during the entire study period. This gave little to no room for improvement.

An important strength of the current study is its mixed-methods design which provides a strong understanding of the topic (Creswell and Creswell, 2017). The population of interest is a very specific patient group. To our knowledge, this was the first study to examine first-person experience of biocueing in forensic psychiatric patients with ASD and/or ID. Despite the difficult patient group, all patients who started the intervention took part in the interviews. This provided us with a varied overview of experiences, which contributes to the further development and implementation of biocueing.

This study also had several limitations. First, the small sample must be acknowledged, which is mainly due to the very specific population of interest. Second, with regard to the exploration of trends in aggression in self-harm it appeared that most patients did not (or barely) show any of this behavior during the entire study period. Given the sample of forensic patients, the majority of whom had a history of violence, this observation suggests that the outcome measure (SDAS) was suboptimal. SDAS is a behavioral observation scale that was scored by nurses on the wards (Wistedt et al., 1990). Although there were little missing data, nurses were not able to observe patients all the time, especially those patients who had daytime activities outside the ward. Moreover, SDAS is designed to measure all forms of aggression, including subtle behavior. It is well possible that these behaviors were overlooked. These findings are in line with other research using this outcome measure (Klein Tuente et al., 2020). Also, it must be emphasized that all patients were admitted in a forensic clinic, this could have a preventive effect in itself.

For future research, we would advise to not only focus on forensic inpatients with ASD and/or ID, since biocueing seems also very suitable for outpatients and non-forensic patients with ASD and/or ID. Also, it is advised to not only track incidents of aggression but also study the subjective experiences of patients and their caregivers with regard to the identification and regulation of emotional and bodily responses, for example using the Multidimensional Assessment Interoceptive Awareness (MAIA-2) or the Difficulties in Emotion Regulation Scale (DERS). Future research should not only focus on the effect of biocueing on aggressive behavior, but on its effect on emotion processing in a broader

sense. Also, for future research it is important to examine the impact of biocueing on heart-rate activity and awareness. Furthermore, use of another smartwatch with improved battery life is recommended, for example the TicWatch Pro 3. Finally, future research should include longer follow-up measures to examine whether biocueing can be used as a prosthetic to mimic emotion processing or biocueing can be used as a training tool to improve emotion processing, i.e. is support through biocueing permanently required or will patient eventually be able to improve their emotion processing skills to a level where support through biocueing is no longer required.

To conclude, the key finding of this study is that forensic psychiatric patients with ASD and/or ID are willing to use biocueing in clinical practice. The results contribute to the development of a biocueing application that is actually feasible for patients. The present study reveals the need for embedding the technology within current treatment and providing simple and direct explanations on what the technology can and cannot do.

CRediT authorship contribution statement

Rianne Bosch: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Project administration. **Farid Chakhssi:** Conceptualization, Methodology, Writing – review & editing. **Matthijs L. Noordzij:** Methodology, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

All authors declare that they have no conflicts of interest.

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