Monitoring and Supporting Engagement in Skilled Tasks: From Creative Musical Activity to Psychological Wellbeing

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ABSTRACT

While good physical health receives more attention, psychological wellbeing is an essential component of a happy existence. An everyday source of psychological wellbeing is the voluntary practice of skilled activities one is good at. Taking musical creation as one such skilled activity, in this work we employ an interaction method to monitor varying levels of engagement of musicians improvising on a desktop robotic musical interface (a network of intelligent sonic agents). The system observes the performer and estimates her/his changing level of engagement during the performance, while learning the musical discourse. When engagement levels drop, the musical instrument makes subtle interventions, coherent with the compositional process, until the performer's engagement levels recover. In a user study, we observed and measured the behaviour of our system as it deals with losses of performer focus provoked by the controlled introduction of external distractors. We also observed that being engaged in our musical creative activity contributed positively to participants' psychological wellbeing. This approach can be extended to other human activities.

1. INTRODUCTION

Through life, individuals develop skills in activities that they find interesting and at which they excel. Such skilled activities often combine intellectual, crafting and creative dimensions: from cooking and knitting to writing, drawing or, in this case, performing with a new musical interface. Practising such activities in an autonomous and voluntary way can bring great satisfaction and sense of purpose to a person, who finds the opportunity to challenge the limits of one's own acquired mastery. The confluence of these three characteristics in an occupation - autonomy, mastery and purpose - has been identified and persuasively proposed as a popular recipe for personal fulfilment at work [1]. In the wider scope of life, these three characteristics are also part of a set of six ingredients that have been identified as important for a healthy, actively-positive psychology in adult life: autonomy, (environmental) mastery, purpose (in life), self acceptance, positive relations with other people and personal growth [2]. Psychological wellbeing is an essential aspect of general wellbeing that traditional medicine does not take care of as a priority in every case. However, it is essential for a happy existence, and being engaged in skilled tasks provides much of such satisfaction and subsequent psychological wellbeing [3].

In the work that we present here, we focus on exposing the centrality of the individual's engaging experiences in psychological-wellbeing enhancing musical activities. We seek to amplify the experience by mediating between the person and the activity in two complementary ways: (i) by monitoring the level of engagement of the person during a musical activity, and (ii) by having the object of the activity itself respond in subtle but meaningful ways to the music composition led by the person, in order to maintain consistently high levels of engagement. We build on work that we developed earlier [4], regarding the machine recognition and monitoring of the engagement level of an individual that is immersed in a musical task with digital environments. The work so far has focused on recognising levels of immersion of musical performers during creative improvisation with a desktop Network Of Intelligent Sonic Agents (NOISA), the musical instrument itself. By combining the monitoring of facial expressions, bodily movements, actions of the hands and the evolution of the sonic production, an initial setup has been validated to successfully estimate levels of engagement at each time of the creative musical process [5].

As the main technical contribution of this paper, we add to the engagement monitoring functionality that NOISA had, a *new response module*, which preserves high levels of engagement in a musical activity when these appear to fade. In this paper, we report a new study conducted in the new NOISA environment that aimed at evaluating the functionality of the response module and the music composition task's effect on the participant's psychological wellbeing. First, we evaluated the system's functionality to identify instances in which we observe a drop in the level of engagement of the person with the musical activity. Secondly, we evaluated the response module's functionality to intervene in subtle ways in order to "rescue" dropping levels of engagement back to higher levels that are associated with a satisfactory creative experience. Lastly, as happiness and wellbeing crucially depend on the activities we engage in [3], in this user study we aimed at understanding whether a satisfactory musical experience could indeed contribute towards the preservation of psychological wellbeing, as we proposed in the beginning.

2. RELATED WORK

In spite of being a commonly mentioned parameter in music research, the mere act of obtaining a unified and consistent definition for 'engagement' represents a surprising challenge. In the field of education, Appleton [6] points the discussion towards separating engagement from motivation: the latter [7] provides an answer to the reasoning behind a specific behaviour depending on the characteristics of the personal energy invested in said situation, whereas engagement refers to the level of focused involvement [8], or "energy in action, the connection between person and activity" [9]. When applied to musical activity, engagement may also have a positive connotation, described as a state of sustained, undivided attention and emotional connection towards creative musical performance [10] or sometimes as a neutral parameter prone to be measured and evaluated in interdependent values for attention, emotion and action [11].

Similarly, there are other studies exploring music as a creative activity that contributes to the general wellbeing. An example demonstrates how active music-making improves wellbeing and overall comfort in a large sample of hospitalised children with cancer [12]. This study draws upon previous research featuring live music therapy that promotes interaction through voice and body expressions, recognising the benefits of interactivity in opposition of listening passively to music as a therapy [13]. While previous studies delineate a methodology for therapy rather than the design of an interactive system, there are examples of interactive tools aimed at positively impacting in wellbeing through rhythmical movement with music as a central element [14, 15]. There is also the precedent of an interactive application to engage patients with dementia in active music making without pre-existing skills [16]. In the same vein, we found an interactive technology tested in children with disabilities and aimed to study how music interaction can "become potentially health promoting" [17].

As a concept, psychological wellbeing is subjective, relative and prone to change with ease. However, it is possible to find specific sonic characteristics that have proven to affect positively an individual's perception of comfort and wellbeing. For instance, in the context of music, some studies indicate that fast and slow tempos are associated with happiness and sadness, respectively, as are major and minor modes [18, 19]. Loud music has proven to be in cross-cultural studies as an universal cue for anger [20]. Timbre is ambivalent, although several studies indicate that attenuation of high frequencies can be a difference between anger (unfiltered) and tenderness (attenuation) [19]. Although affective associations of both tempo and mode are fairly well established, effects of other musical characteristics are poorly understood. On the cognitive level, David Huron's ITPRA (Imagination-Tension-Prediction-Response-Appraisal) theory studies the relationships between affective consequences and expectancies in music [21], establishing clear connections. Evidence also suggests that some auditory illusions, such as Binaural Auditory Beats, are associated with less negative mood, notably affecting performance in vigilance tasks of sustained concentration, particularly when they occur in the beta range (16 and 24 hz) [22].

Regarding the concept of musical interaction being perceived as rewarding, the Orff approach states that improvisation with pentatonic scales, with bars and notes removed, is always satisfactory and encourages freedom from the fear of making mistakes [23]. The goal is for everybody to experience success and appreciate the aesthetic in music almost immediately, rather than having to learn notes and rhythms before anything satisfying is accomplished. Percussive patterns were important in his theory, as they appeal to a primal essence in human beings and allow tempo and beat to be experienced rather than learned. We incorporated many of these ideas into our work while designing the response module and its implementation in a music-making creative activity that can link cognitive features and physical movements together to pay attention for immediate responses. This is a generic hypothesis of research in cognitive neuroscience of music and the concept of music, mind and body couplings that our project takes into account [2, 24]. The former points out the benefits of music as a therapeutic tool and it can improve recovery in the domains of verbal memory and focused attention. The latter indicates its impact on social and individual development through active engagement with music.

3. NOISA

As mentioned, NOISA (Network Of Intelligent Sonic Agents) is the robotic musical interface that we took into use and built on for this research work. NOISA consists of three instruments for music creation, a Microsoft Kinect 2 camera and a central computer. The three instruments are physically identical from each other. Each instrument is built inside a plastic box. The interface for playing each instrument consists of two handles designed to provide an ergonomic form for grasping them from several directions, which can also position themselves actively, thanks to DC motors (the robotic interactions with the physical medium). The handles are attached to a motorised fader, which served both as position indicator and as active position controller. The hardware in each box includes an Arduino, a Raspberry Pi, two motorised faders with extra large motors, two capacitive touch sensors on the handles, and an embedded speaker. In each instrument, sound production is largely based on granular synthesis and phase vocoder algorithms de-fragmenting radically small fragments of pre-existing pieces from the classical music repertoire.

3.1 Response Module

Based on Huron's ITPRA theory, we concluded that working in a stronger Prediction-Response musical connection would likely produce an affective response evaluated as positive [21]. Huron also proposes that recognisable patterns are a common characteristic in music associated to positive emotional responses. Thus, we decided that for the current iteration of NOISA, the system would recognise, store and playback musical patterns of 2 seconds of activity, which the performer could easily identify based on the data inputted. In order to avoid to solely reproduce an exact copy of the gesture performed by the performer, we also programmed a set of variations, based on the music composition technique of motivic-through composition, also known as thematic development. This technique has been used successfully in classical music from the common practice period (barroque to late XIX century), and also in post-millennial music, including mainstream genres [25].

We defined the gesture by recording a maximum of seven-second long movements. The data recorded included the engagement value, device identification, energy (measured in decibels), spectral centroid (average of most prominent frequency ranges over time), movement of the handlers and time-stamps. Recording was initiated when a new movement was detected, and stopped when inactive for longer than one second. The gesture playback was activated depending on the performer's engagement in the task, activating more often when the engagement was low. The playback gestures were then chosen from a fifteen-minute interval. Gesture data was measured against weights that were defined by the energy mean value, spectral centroid, spectral energy and amount of time elapsed since the recording was made. The result was that, when the engagement was higher, a larger set of chosen gestures was used. When lower, newer patterns were chosen matching the readings from the performers currently playing, to make the pattern more recognisable.

The first choice of instrument for playback (out of the three autonomous sonic agents) was the instrument on which the gesture to be reproduced had been recorded. If that instrument was in use at that time, one of the other two instruments was randomly selected instead. There were four variations of response playback: the recording itself, an inverse (negative), a reverse and an inversed-reversed version of the recording. The inverse was mapped into the right range with the help of the highest and the lowest values. The engagement level of the performer was the deciding factor for the chosen gesture variation. When less engaged, the pure recording was the most common choice. When engagement became higher, the performer experienced a larger set of variations.

3.2 Hardware Design

The new response module required more precision than the initial NOISA design could handle, so a new inner structure for the instrument was designed. Most of the hardware parts were custom made with 3D printing, computer numerical control (CNC) milling and laser cutting (see Figure 1). After a few iterations we reached the current state. Aluminium tubes were added to make the handles stronger yet light. The slide-bearings for the aluminium tubes were CNC-milled for an exact fit. The handles were redesigned to manipulate the added weight, using additional timing belts and aluminium pulleys. The benefit of these changes was lower friction from the handles. For the outer shell to be strong enough to hold the new structure, we added supporting layers and attached everything together with custom-made corner-irons. The handles of the instrument were also redesigned, with holes for the aluminium rods and added space for the pressure sensors. To detect the pressure, two pressure-sensitive conductive sheets were sandwiched between layers of copper tape. By reading the change of the resistance, the amount of pressure could be detected.

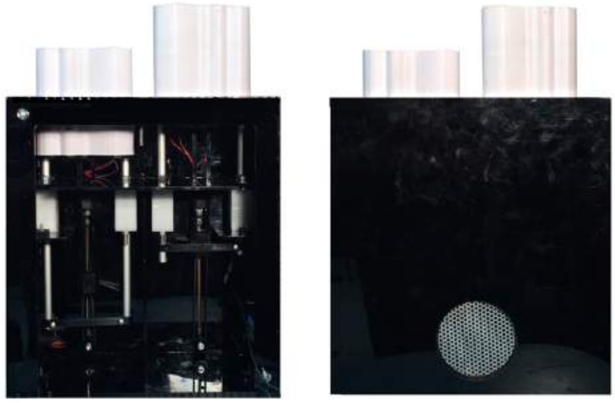

Figure 1. New interface design of the NOISA instrument

4. USER STUDY

To review our main research goals in this work, we wanted to observe, first, if participating in the skilled activity of improvising music with our accompanying robotic instrument showed any signs of being subjectively beneficial for people. Such outcome would suggest that our improvisation activity might be eligible as one of the many possible skilled tasks in the scope of this study (see again our discussion about this in the introduction). Second, we wanted to observe our interactive system in action, both monitoring the levels of engagement with the activity (a functionality already validated for earlier versions of this instrument), and, more crucially, intervening (i.e., coaching) when the performer's level of engagement dropped to low levels. As the main technical contribution, we wanted to observe if the system was able to refocus the flow of the performer's activity until higher engagement levels were again measured.

To do all of that, we designed and conducted a two-part user study in which 15 voluntary participants (8 females) took part. The first part aimed at recording a subjective measure of wellbeing before and after a performance session in which a person could improvise under normal conditions. In the second part, in contrast, we provoked the loss of focus of the participant in the improvisation activ-

Figure 2. Users developing the task

ity, and we observed if the system could observe the corresponding drop in engagement, and if the instrument could intervene collaboratively until engagement was recovered.

After a general description of the whole session and after obtaining consent, the first part of the user study started with the participant filling out the PANAS questionnaire (The Positive and Negative Affect Schedule) [26]. This is a validated questionnaire that evaluates positive and negative affects using a psychometric scale, and the change in those within a specific period of time during which some treatment activity took place (in our case, a performance session with our collaborative musical instrument). PANAS uses 10 descriptors per category of affects, showing relations between them with personality stats and traits. PANAS has been successfully applied to measure overall psychological wellbeing before, and after a musically creative activity [27]

The participant was then introduced to the NOISA instrument, with explanations about how it works, followed by a period of hands-on familiarisation with it (typically for about three minutes). Once the participant felt confident enough, the first music performance task was described, which required performing a piece according to a somewhat restrictive set of rules (we wanted to reduce variability in the performing activities at this stage in the study). In particular, the participant would be asked to start performing with a specific instrument (Agent 1), then repeat the given gesture with the middle instrument (Agent 2), finishing with inputting the same repeated movement in the third instrument (Agent 3), resulting in a piece that lasted for between three and five minutes. Once this was done, NOISA would have typically started to make automatic responses. At this moment, the participant was asked to explore freely any of the agents, and once the participant was ready to finish, she/he had to manipulate the handles in Agent 1. The participant was required to stop any input activity as an indication of the end of the music task.

After finishing the task, the participant was asked to fill in again the PANAS Questionnaire in order to compare the impact of the task in the overall sense of psychological wellbeing. Following that, the participant was asked to evaluate the system's usability by filling in the online version of the System Usability Scale (SUS) designed by our research group to facilitate the data gathering and analysis. SUS has "provided with that high-level measurement of subjective usability, and over the years the work done by other researchers has indicated that it is a valid and reliable tool" [28].

For the second part of the study (designed to observe the engagement tracking and recovery functionalities of our interactive system), we asked the participant to repeat the same musical task, extending it for a period of four minutes. This time we tracked and logged the level of engagement over time. We scheduled two events sufficiently distracting at 1:30 (door opening, person coming in and loudly manipulating a cardboard box) and a more sublte event at 3:00 (phone ringing). We drew inspiration from previous studies measuring the impact of distractions in psychological wellbeing during a skilled activity [29]. The participant was not aware that such events would take place, nor he/she was prepared for them. The total duration of the test was approximately 30 minutes (see Figure 2).

5. RESULTS

The PANAS scores are divided in Positive Affects (PA) and Negative Affects (NA). According to the PANAS documentation, the mean PA scores for momentary (immediate) evaluation are 29.7 (SD = 7.9). Scores can range from 10 to 50, with higher scores representing higher levels of positive affect. For Negative Affects the mean NA score for an equally momentary evaluation are 14.8 (SD = 5.4). Scores can range from 10 to 50, with lower scores representing lower levels of negative affects.

During our tests, we obtained a PA score mean (Before the activity) = 30.57 (SD = 3.89) and a PA score mean (After the activity) = 34.21 (SD = 5.14). In addition, we collected a NA Score (Before the activity) = 15.57 (SD = 6) and a NA Score (After the activity) = 12.30 (SD = 3.30). This means an overall improvement of 3.64 PA points and 3.27 NA points. By adding PA and NA scores, we found that the overall improvement in the reported psychological wellbeing was of 6,91 points, which in a range of 10 to 50 in the PANAS range represents an overall improvement of 17.27% after 3 minutes of activity with our system. In addition, 30% of the participants reported an improvement of more than 10 points in the PA affect score

In our paired before/after test, for Negative Affects the two-tailed p value equals 0.0029 (t = 3.5979), a statistically significant difference (significance level $>$ 99%). Regarding the Positive Affects, we obtained a p value of 0.0699 (t = 1.9750), which is also statistically significant (significance level $>$ 95%).

Regarding usability, the System Usability Scale research drew the average of 68 points in the scale (from 0 to 100). Sauro [30] found that when people rate a system or product with a SUS score of 82, they are likely to recommend a system or product to a friend or colleague (Net Promoter Score). After evaluating our system, the participants gave it a SUS mean value of 73.9 (SD = 11.33) which means 5.9 points above average. One third of the participants gave our system a SUS score of 82 or higher, potentially becoming a "promoter".

Finally, our engagement graphs over time showed that the system was able to identify and measure a distraction event in 73.33% of the participants, impacting the overall engagement by 0.2 points or more, in a scale of 0 (total disengaged) to 1 (full engagement). Our engagement scale is also divided into categories, where 0 to 0.3 means low engagement, 0.3 to 0.6 medium engagement and 0.6 to 1 high engagement. Calculating every time a distraction had an impact in the engagement, there was an overall average of 0.41 sudden decrease (SD = 1.40). As the NOISA system reacts once it detects a drop in the overall engagement, the level of focus was effectively regained to a stable level before the distraction event in a mean time of 10.07 seconds (SD = 7.15). Two engagement over time graphs for the participants 10 and 11 (see Figure 3 and 4) are included to demonstrate an example of a case where our engagement prediction system detected both distractions (90 and 180 second mark, respectively), managing to regain focus of the participant through autonomous counteractions.

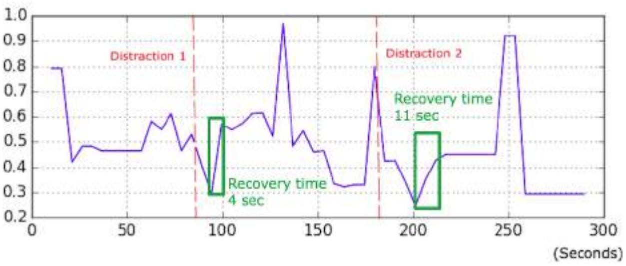

Figure 3. Engagement over time graph of the participant 10

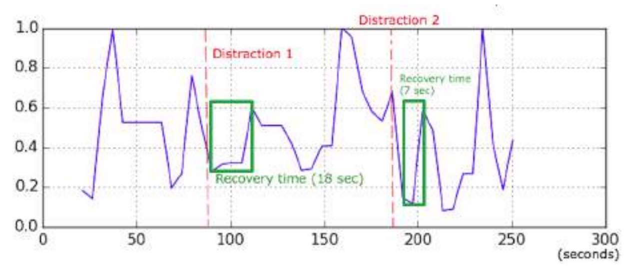

Figure 4. Engagement over time graph of the participant 11

6. ANALYSIS AND DISCUSSION

The results presented above show that the design of the response module provided beneficial results for the participants. The response module could successfully maintain and strengthen the level of engagement in a skilled activity of musical improvisation with NOISA instruments. The resulting experience of such interaction was also likely to have contributed positively to the psychological wellbeing of the participants.

Judging from the quantitative data obtained through the PANAS questionnaire, the average levels of Positive Affects were higher after finishing the test, and the Negative Effects were lower after completing the task. In case of Negative Affects, the difference was found to be very statistically significant. In the PANAS scale, the Negative Affects scores decreased from above the mean (15.57) to below it (12.30). Even though the impact on the Positive Affects was found to be not quite statistically significant, we consider the overall improvement of 17.27% positive considering the short amount of time spent with the system during our task. The creative activity facilitated by NOISA system proved to be statistically significant to impact on the Negative Affects described in PANAS (Distressed, Upset, Guilty, Hostile, Irritable, Ashamed, Nervous, Jittery and Afraid), which shows that the musical task showed some capabilities during the test that can be successfully applied to help reducing the subjective perception of worry, stress and other negative personality traits of the participants.

The engagement estimation results indicated effectiveness when detecting and maintaining the focus level of the participants. In that sense, being able to measure at least one of the distractions in 73.33% of the participants is satisfactory, considering that while being observed, the participant could feel compelled to keep his/her attention to the task at hand. This situation would avoid us to detect any distractions in their physical body movements. The response module was capable of recovering attention and focus from the participants in an average time of 10.07 seconds after the distractions. We can note here that our current contribution to NOISA system provided an engaging interaction that was gradually and progressively built up by the participant's active and continuous involvement in the musical activity with NOISA instruments.

Similarly, we observed that both our new hardware design and response module were evaluated by the participants as easy to use, obtaining consistent above-average scores in the SUS scale. In addition, a large portion (one third) of the participants cataloged it above the 82 mark, which is particularly positive considering that we asked non-specialist individuals to evaluate a new musical interface. Our sample consisting of 15 participants might be considered small; however, Tullis and Stetson [31] have already demonstrated the reliability of SUS in smaller samples (8-12 participants).

7. CONCLUSIONS

Based on previous literature, it is clear that designing for wellbeing is strongly linked with the psychological understanding of wellbeing, positive experience and physical activity [3]. The purpose of our project was to establish a situated musical activity for the user to be engaged in, attempting to achieve the goal of enhancing psychological wellbeing. Our design was grounde in a concrete context (creative musical overall process) and guided by the functionality (hand-held interface) as well as through subtle interaction (counter-responsive musical actions). We observed and measured the behaviour of our system as it deals with losses of performer focus provoked by the controlled introduction of external distractors. During the tests, we observed indications that being engaged in our musical activity contributed positively to participants psychological wellbeing. Encouraged by our initial results, we plan to continue our research by including in a future study a comparison with a control group, which will enable us to draw in a longer term more comprehensive conclusions of the impact of the activity with NOISA in the pyschological wellbeing of the user.

We also aim to investigate the application of a similar engagement-monitoring technique in a broader scope of skilled, potentially mentally absorbing actions with people working in different occupations. A foreseen psychological wellbeing application scenario that will be implemented in the future phases of the project, could be the non-intrusive recognition of changes in patterns of engagement that a person presents when carrying out different creative tasks with digital environments, which could signal changes in their mood, psychological health or deterioration of their cognitive capacity (early diagnostic goal). This application requires a new hand-held interface to be designed and implemented which will be fully integrated with the engaging monitoring and the new response module in NOISA system. Through subtle external actions, the new interface and the digital environment could assist the person to regain focus and engagement with the creative task in hand, which might be beneficial for the successful completion of the task (assistive living goal), and to do so with an enhanced sense of control, accomplishment and satisfaction (psychological wellbeing goal) in a creative process.

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