Individual differences and the Sense of Embodiment: looking for a correlation in a out-of-body experience

1st Sara Falcone
University of Twente
Enschede, The Netherlands
s.falcone@utwente.nl

2nd Saket Pradhan
University of Twente
Enschede, The Netherlands
s.pradhan@student.utwente.nl

3rd Jan van Erp
TNO
Soesterberg, The Netherlands
jan.vanerp@tno.nl

4th Dirk Heylen
University of Twente
Enschede, The Netherlands
d.k.j.heylen@utwente.nl

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This is a preliminary study to test and measure whether individual differences can affect the Sense of Embodiment (SoE). The SoE is the experience that an external body or part of it is perceived as one's own. We apply this concept to teleoperation tasks, namely the remote control of a machine or device [1]. Studies demonstrated that a high level of Sense of Embodiment (SoE) can improve the performance in teleoperation tasks [2]–[4]. This is because when a high level of SoE is achieved, the operator's perception of the remote device as mediator is lower [5] and the teleopration system is more transparent. To test the possible effect of individual features on the SoE, we focus on a particular target of individuals: people with a high level of proprioceptive information level (gymnasts and dancers) who should be more resistant to the embodiment illusion. This effect has been hypothesized but never tested [21]. We will focus on the three main components of the SoE: the sense of ownership [6], the sense of agency [7] and the sense of self-location [8].

We realized a between group design, in which we compared a group of dancers/gymnasts and a group of non-dancers/non-gymnasts on the same tasks. In order to verify that each participant was assigned to the correct group, apart from the profiling questions about their physical training, they had to perform a battery of tasks to test their proprioceptive level, based on a previous study realized by Jola et al. [9].

For the experiment setting and tasks, we based our design on the out-of-body experience (OBE) as described by Ehrsson [10]–[13]. In our case, there were two experimenters (see Figure 1): *Experimenter 1* was the stimuli provider, and *Experimenter 2* was the one wearing a VR headset (as the participant) on which we positioned a stereo-camera and standing on the left of the participant. The participants wore the same VR headset of *Experimenter 2* for the full duration of the experiment and both the participants and *Experimenter 2* could see the same images transmitted by the stereo-camera positioned on the *Experimenter 2*'s headset. Therefore, the participants were experiencing the first person perspective (1PP) of *Experimenter 2* and the latter could be sure of what the participants were seeing. Moreover, the *Experimenter 2* and the participants wore gloves of different colors. We asked the participants to wear the glove before wearing the headset, in order to ask them, after the Agency task, to tell us the color of the glove that they were wearing. We used this question to check the SoE, particularly the sense of ownership. We designed three tasks based on the literature:

1) *Cross-modal Congruency task (CCT)*: this kind of task is a common measure of embodiment [14]. We applied two types of CCT. In the first task, we asked the participants to tell us as soon as possible, if they felt touched by a stick or not (the stick was controlled by *Experimenter 1*), and we measured the reaction time. We compared performance under two conditions: congruent in which visual and tactile cues matched and incongruent in which we did not touch the participants with the stick, even if they saw to be touched (because the experimenter 2 was actually touched and the participant was experiencing his visual perspective). In the second task, we touched the participants with three different objects with a different stiffness: a) the tip of a pen, b) a brush, and c) a soft ball. As above, visual and tactile information could be congruent or incongruent. We asked the participants, after each touch, to tell us if they felt a), b) or c).
2) *Agency task*: we placed a tablet in front of the participants and a second tablet at the same location and distance in front of *Experimenter 2*. Each tablet ran a drawing software program with an image with some enumerated dots spread in the drawing. We asked the participants to connect the dots sliding the index finger of the dominant hand from the center of one dot to the center of the next dot. The participants had to move to the next dot every time that *Experimenter 1* gave the instruction to do so. *Experimenter 1* placed the hand of the participant and of *Experimenter 2* simultaneously on the center of the first dot of their own tablet in order to make them start from the same location. The participants moved their arm while seeing the movements of the arm

of *Experimenter 2*. We took track of each point they touched during the task on the tablet (using the drawing software). With this task we measured the agency and the proprioceptive drift (measuring the distance between the point touched by the participants and the target point). This task was particularly interesting to design and add to our battery, for several reasons. In OBEs, usually the sense of agency is not tested. For instance, in the rubber hand illusion, the participant is just an observer. In our case, the purpose of the study was to apply the findings in teleoperation tasks and scenarios in which agency is important. In addition, the task is comparable to a task that is often used in batteries applied to test and measure the proprioceptive information level of people who are blind [15]. Since in our experiment the participants did not see how they moved the hand, but they were sort of blind-folded, we could find an analogy in the condition.

3) *Scaring task*: to break the illusion, we used the surprise effect through pretending to stab the participants with a fake knife (the ones with the retractile fake blade). This task was useful to detect a peak (expected to be larger in case of embodiment) in the physiological measure that we adopted (skin conductance response).

According to the literature [5] there is no standardized evaluation of the SoE. Therefore we used a combination of qualitative and quantitative measures. We intend to use this same combination of measures for all the experiments that we will realize using this set-up. Standardizing the measures makes it easier to compare future results.

- Qualitative measures: we adopted a questionnaire structured in three parts:
  1) Profiling information: gender, age, if the participants practice a sport, which sport, at which level (competitive or amateur); if they had medical condition which affected their upper body muscles or nerves.
  2) OBE pre-screening [18]–[20]: questions in combination with the tasks and some other checks, such as to tell us the color of the raincoat that s/he is wearing.
  3) Agency and ownership questionnaire [16], [17].
- Quantitative measures:
  - Propriocetive drift (measured from the Jola et al. task that we replicated [9] and the agency task);
  - Reaction time (measures from the CCT1);
  - Skin conductance response (measured for all the duration of the experiment).

Starting from this preliminary experiment, the idea would be to start a series of studies in which we will test individuals with target features, especially their proprioceptive information level, and we will keep collecting the profiling information and the embodiment evaluation in order to see if we can observe a systematic relation.

If we find that the profile of individuals predicts their susceptibility to the SoE illusion, this would be useful to explore if we can improve the operators' task performance. For example through training the use (or rather ability to ignore) proprioceptive information. We hope that this could improve the efficiency and reduce training time in teleoperation. This is relevant in teleoperation, but also in gaming and the use of prostheses.

Fig. 1. A demonstrative picture of the setup.

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