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학 술 논 문

Investigation of the Influence of Induced Mood on Rehabilitation Engagement: a Study Focusing on Muscle Activity

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Abstract: Engagement is an important factor in the field of rehabilitation as it is a known factor that have a positive influence on functional gaining in people who receive rehabilitation therapy. Although a number of measurements for engagement have been recently developed, investigation of possible factors that may have influence on engagement is not well established. Currently available evidence suggests that engagement is affected by mood and it is hypothesized that a personal factor may contribute to engagement. Therefore, this study aims to test the hypothetical relationship between mood and engagement while performing a manual dexterity task through an experiment in healthy participants prior to investigation on people with medical condition who requires rehabilitation therapy. After inducing target mood (positive or negative mood) for study participants by asking them to recall autobiographical memories, change in muscle activity, which was operationalized as an indicator of engagement, was investigated. Electromyogram (EMG) was recorded from four muscle areas in non-dominant hand side to quantify muscle activity. The results show that the target moods were appropriately induced with the method. Although there were subtle differences in the level of engagement between different moods, certain variables derived from muscle activity were significantly different; mean amplitude for wrist extensor EMG showed significant difference between different moods ($Z = -2.023$, $p < .05$) indicating that muscle activities in the wrist extensor are greater for positive mood than negative mood region during manual dexterity task. Meanwhile, performance outcomes of Minnesota Manual Dexterity Test (MMDT), such as mean completion time and number of errors, between moods showed no significant difference in two different moods, resulting in MMDT administration may not be useful task in distinguishing the level of rehabilitation engagement.

Key words: Electromyogram (EMG), Manual dexterity, Physiological response, Psychological influence, Rehabilitation engagement

I. Introduction

As populations are aging, the number of people who are vulnerable to disease is also in a rising trend. In particular, stroke has been named as one of top 10 leading causes of death in South Korea and a considerable number of people with the episode acquired disabilities. This results in increased number of people who require rehabilitation to recover or to maintain their functional abilities. Previously, it has been emphasized that effective interventions should be developed and provided for stroke patients for their rehabilitation. This has led to increasing numbers of rehabilitative interventions that employ advanced technologies, for example, wearable sensing system, or robotic and virtual reality rehabilitation system [1-3]. Such high technologies have served to provide effective means of rehabilitation methods, which not only help therapists make relatively less physical efforts for their clients, but also provide equivalent quality of service during rehabilitation sessions [4]. However, active role of patients during the process of rehabilitation is becoming more emphasized requiring the patients to be pro-

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active to gain more improvements in functional outcomes [5]. This trend is supported by the increasing number of studies looking into the importance of client motivation, engagement, and participation through the course of rehabilitation [6,7]. This is due to the fact that engagement and participation are known to be associated with enhanced rehabilitation outcomes [8]. Researchers have tried to evaluate patient engagement [6,7,9], influences of increased engagement and functional improvements. Lenze and his colleagues investigated patient participation, which has been operationally defined as an demonstrating component for engagement in rehabilitation [10], to rehabilitation therapy sessions by comparing the level of participation quantified with Pittsburgh Rehabilitation Participation Scale (PRPS) [6]. The tool is a single item observation-based tool that patient participation to the session is rated by occupational therapists or physical therapists. They found that the score of PRPS was positively correlated with functional gaining and the score was the strongest predictor of outcome among others, such as gender, length of stay, the level of functional abilities at admission and discharge, and race. In addition, there are more measure to assess engagement and their findings are consistent [7,9]. Although positive influences of higher level of engagement on functional outcome are evident, what may influence the level of engagement throughout rehabilitation has not been well understood. Therapeutic connection between therapists and clients helps to maintain positive mood resulting in enhanced engagement [11] and impairment in mood may affect a patient's ability to participate [7]. These suggest that moods may be an influencing factor to engagement within rehabilitation. While there may be more than one influencing factor to engagement, this study only considers a personal factor of possible influencing factors. In this study, mood is operationalized as the personal factor. In order to investigate the relationship between moods and engagement, it is necessary to induce target moods in a sufficient manner and to examine the impacts of mood on the level of engagement while performing a task. A manual task for training dexterity and a method for inducing mood were employed to test the objective of the study and they will be explained in the next section.

II. Materials and Methods

This section describes the details with regards to participants, materials, and research design.

1. Participants

Five healthy participants were recruited for the experiment at a university. All of them were female and mean age was 23.8 (±0.98). Every participant was right-handed. While the participants were blinded to the purpose of study, they were given explanation of experimental protocols and instructions prior to experiment administration. None of them appeared to have difficulty in following instructions. Informed consent was acquired before experiment administration. Study protocol was approved by the Institutional Review Board on Human Subject Research and Ethics Committee at Soonchunhyang University, Cheonan, Korea (No.: 1040875-201612-SB-045).

2. Mood induction

In order to induce positive or negative state of mood, the participants were required to recall their own memories accordingly. One of mood inductions that has been traditionally used in the field of psychology is to request study participants to recall their personal episodes in the past, in which they were in either positive or negative mood due to the episode [12]. This method expects the affect states of the participants will be directed by recalling the events. For a pleasant affective state, they were asked to remember happiest memories for five minutes vividly as possible and write it down. In addition, they were told to write down and try to feel the same way the participants did before. On the other hand, they were required to recall angriest memories for inducing negative mood.

3. Self-assessment manikin (SAM)

Self-Assessment Manikin (SAM) is a 9-point Likert scale to quantify emotions or moods in the three dimensions, valence, arousal, and dominance [13]. This tool consists of pictures with different intensity level of valence, arousal, and dominance. Pictures for valence in SAM ranges from frowning and unhappy face to smiling face (score from 1 to 9). For the arousal dimension, there are figures representing the state from relaxed to excited (1 being relaxed and 9 being excited). Finally, the dimension of dominance, people can rate how much they feel in control (1 being controlled whereas 9 being in control). Since the tool is a non-verbal scale, it offers several advantages. First of all, it does not take too long to administer. Second, illiterate people also can use the scale. This may be the reason why the scale is widely used internationally. Although the original SAM scale consists of three dimensions, only two dimensions were rated for the purpose of the study.

4. Manual dexterity task

Fig. 3 shows a tool for manual dexterity, Minnesota Manual Dexterity Test (MMDT) (Lafayette Instrument Company) for study participants to perform. Manual dexterity requires fine motor skills and coordination among others to manipulate objects and improving manual dexterity has been one of important functional abilities rehabilitation aimed to improve. In order to investigate difference in engagement between positive and negative mood, a task for manual dexterity was employed. The reliability and validity of the test were confirmed that the tool is able to reliably evaluate manual dexterity [14]. The test materials include a thin foldable plastic board 60 holes where each disk can be placed. Each side of a disk has different colors, red and black. All the materials are put into a carrying case. The tool is a standardized test for fine and gross manual dexterity as well as hand-eye coordination used in the field of rehabilitation. This tool is also used by vocational evaluators to assess a person's ability that requires manual dexterity resulting in that the MMDT was employed for training manual dexterity of upper limbs in this study.

The test comprises 5 subtests such as placing, turning, displacing, one-hand turning and placing, and two-hand turning and placing. A test administrator needs provide a cue to prepare the test by saying "Ready" and a cue to start the test by saying "Go" for assessment. Next, the test administrator calculates completion time by subtracting finishing time in minutes and seconds from the point of starting time. For the purpose of the study, participants were required to only perform one hand turning and placing with their non-dominant. The direction of the placing and turning task depends on the side of non-dominant hand. For example, the direction would be left to right if non-dominant side of a participant is left.

5. Electromyography (EMG)

Electromyography (EMG) is a diagnostic technique for recording and evaluating electrical activity or muscle response originated by a nerve's stimulation of the muscle. There are two types of EMG: intramuscular EMG and surface EMG. The former uses either a monopolar or concentric needle electrode, which is inserted into individual muscle tissue whereas the latter records muscle activity from the surface above the muscle using electrodes. Therefore, surface EMG picks up signals from a broader area of target muscles. Since each type of EMG collects and evaluates different source of data originated by nerve and muscle, the selection of appropriate type of EMG may depends on application. However, surface EMG was employed instead of intramuscular EMG as it is a relatively non-invasive method. It is also suggested as a good index, which well represents the intention or effort required to perform a given task [15]. This is supported by studies where employed surface EMG to measure level of engagement to rehabilitation training for upper and lower extremities respectively [16,17]. Therefore, muscle activity was recorded from the participants as a means of index for engagement using surface EMG while they were performing the MMDT. Locations of EMG placements were previously studied in [17] where electrodes were attached to four different regions on non-dominant arm: (1) biceps brachii, (2) wrist extensor, (3) wrist flexor, and (4) thumb abductor. Fig. 4 shows the location of EMG sensor placements.

Firstly, the skin was cleaned using isopropyl alcohol. Next, Wireless Research "Lossless" EMG sensors (Noraxon USA Inc., Scottsdale, AZ, USA) with disposable surface electrodes were fixed in place using double-sided adhesive sticker. The data was collected from the sensors in the designated muscle regions transferred to a Noraxon Desktop DTS receiver (Noraxon USA Inc., Scottsdale, AZ, USA) and common-mode rejection ratio was greater than 100dB.

6. Experimental settings

Fig. 1 shows the experimental protocol. Mood was induced using the autobiographical recall method for each participant. Before the mood induction, they were required to remain calm making little movement for 2 minutes and they rated their current mood state using SAM [13]. Next, either positive or negative mood was induced for 5 minutes and they also reported mood state. After mood induction, the participants performed MMDT as quickly as possible [14]. The procedures were repeated in the same order as the first trial, except that the type of mood that was induced for the second trial was different from the mood induced for the first trial. Fig. 2 shows the experiment setting. MMDT was placed in the center of table (200 × 100 × 100 cm). Distance between disks at the bottom and the top of the board was 10 cm. A camera was placed above the table to record arm motions from the top view.

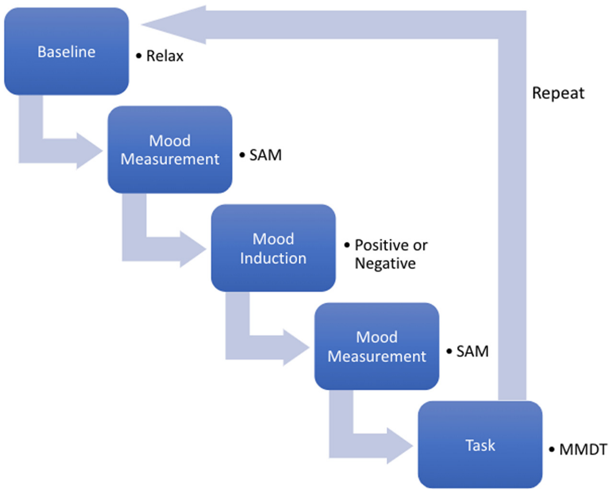

Fig. 1. Procedures for experiment

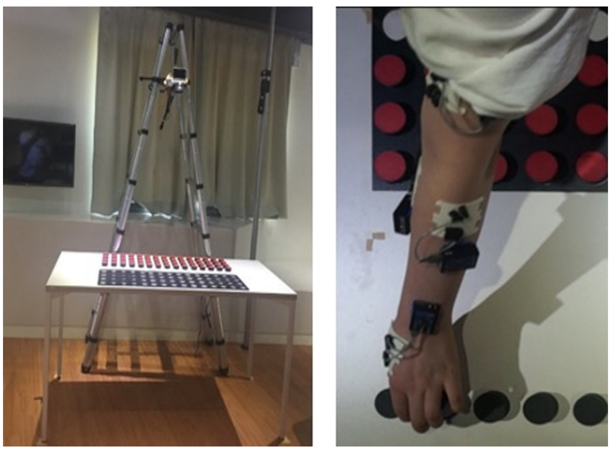

Fig. 2. Experimental Settings: left) Camera recording set up, right) Sample capture of recorded video

7. Signal processing

The EMG signals were sampled at 1500 Hz from all four muscle regions. Firstly, all raw EMG were rectified and filtered by applying a Butterworth band-pass filter (20-500Hz). On one hand, peak EMG during Maximal Voluntary Contraction (MVC) was derived from the combination of root mean square (RMS) with 100 millisecond window and peak value with 1000 millisecond window. On the other hand, full wave rectified signals while performing MMDT task were smoothed using a 100 millisecond RMS window and normalized with the peak EMG from the MVC (%MVC). In addition to mean RMS of EMG, which is suggested to quantify engagement in [17], slope was computed from median frequency as an additional index of engagement since the item has been investigated for muscle fatigue [18].

8. Data analysis

Although the study participants were required to rate their mood in the Likert scale ranging from 1 to 9, the valence score of SAM was converted the range from -4 to 4, in which negative value represents negative mood. Firstly, the SAM score for induced mood states is compared to discover the effect of the mood induction method. Next, the level of engagement, as quantified by variables of EMG. Furthermore, linear regression of mean frequency and median frequency were completed yielding slopes while performing MMDT. Evaluation of MMDT were completed to discover whether there are differences in the variables depending on the mood state. Thus, the completion time was measured and computed. In addition, the number of errors made by the participants were quantified by an experienced occupational therapist who was analyzing the video recorded for arm movements during the MMDT administration. Wilcoxon signed rank test is used for the comparison. Significant level (α) was set at .05. SPSS 12 for window version was used for statistical analysis.

III. Results

This section reports the results of mood induction, EMG measurements, and performance of MMDT. Descriptive and statistical analysis results will be explained below.

1. Mood states

The participants reported their mood in the dimension of valence and affect using SAM after mood induction procedures. Fig. 5 shows the mean score. The mean score of valence and arousal were 0.6 ± 0.89 and 0.8 ± 2.28 for positive mood. On the other hand, they were –1.6 ± 1.81 and 2.4 ± 0.55 for negative mood respectively. The mean scores of valences indicate that the mood induction method appropriately led the participants to intended moods. This was further supported by statistical analysis. There was statistically significant difference in the valence between mood ($Z = -2.032$, $p = .042$). However, the SAM score for arousal did not show the significant difference ($Z = -1.300$, $p > .05$)

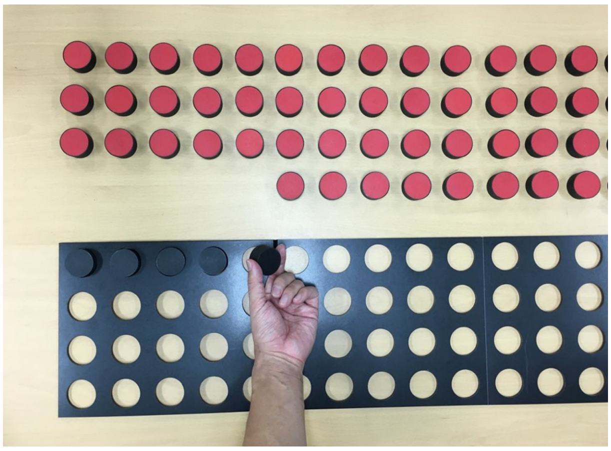

Fig. 3. Minnesota manual dexterity test (MMDT)

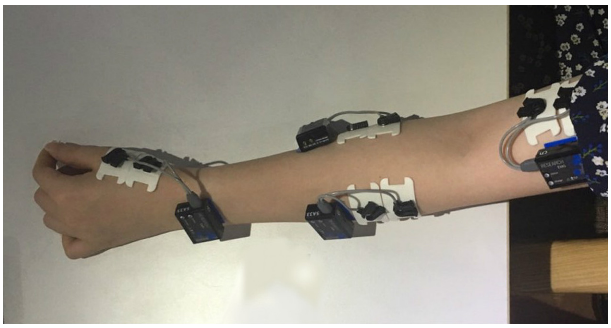

Fig. 4. EMG sensors placements on non-dominant hand

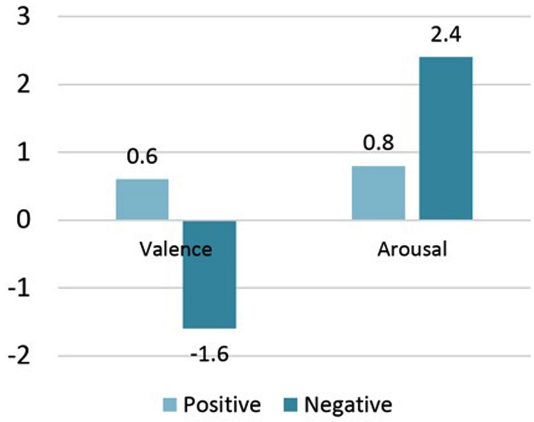

Fig. 5. SAM Mean scores of valence and arousal

suggesting that the mood induction was more effective to change the state of valence with marginal influences on arousal.

2. Motor engagement

Mean RMS EMG (%MVC) from four muscle region are presented in Figure 6 below. Mean RMS value of EMG (%MVC) from biceps and wrist extensor (11.43 ± 5.45%; 14.14 ± 7.00%) were greater for negative mood whereas the values from wrist flexor and thumb abductor were greater for positive mood (7.66 ± 6.50%; 14.75 ± 5.73%). According to the scores of RMS EMG, the highest muscle activation was found in the region of thumb abductor and the least muscle action was seen in the wrist flexor area and followed by muscle activities in the area of wrist extensor.

Firstly, Table 1 summarizes the results of Wilcoxon signed rank test on the mean amplitude and median

Table 1. The results of Wilcoxon Signed Rank Test on mean amplitude and median frequency while performing MMDT

		Mean Amplitude
Biceps Brachii	Z	-1.49
	p	.136
Wrist Extensor	Z	-2.02
	p	.043*
Wrist Flexor	Z	-.67
	p	.500
Thumb Abductor	Z	-.41
	p	.686

frequency of EMG between positive and negative mood. Most measurements did not show statistical differences between positive and negative mood. However, mean amplitude for wrist extensor showed significant difference between different moods ($Z = -2.023$, $p < .05$) indicating that muscle activities in the wrist extensor are greater for positive mood than negative mood region during MMDT administration. The muscle activities in other regions followed similar trend that they were generally greater for negative mood.

Table 2 and 3 respectively summarize the slopes from linear regression on both mean frequency and median frequency over time between induced moods during MMDT administration. Average slopes derived from mean frequency and median were negative value for both positive and negative mood, except biceps and thumb abductor for negative mood, and thumb abductor for negative mood. The results suggest that the level of muscle activities of most muscles studied tend to decrease over time. In addition, there was significant difference in the slope for thumb abductor between moods ($Z = -2.023$, $p < .05$). Although the slopes from the wrist extensor and wrist flexor were not statistically significant between positive and negative mood, they were marginally significant ($p < .08$).

3. Performance of the manual dexterity task

Completion time of MMDT administration are illustrated in Fig. 6. Each mean completion time of the hand dexterity task for positive and negative mood was respectively 156.04 ± 31.90 seconds and 157.56 ± 21.97 seconds. The difference in completion time between positive mood and negative mood were not significant ($Z = -.405$, $p > .05$). During MMDT task, 1.8 ± 0.84 errors were made by the participants when they were inducing with positive mood whereas 3.2 ± 2.28 errors were made for negative mood. Though, they were not significantly different ($p > .05$).

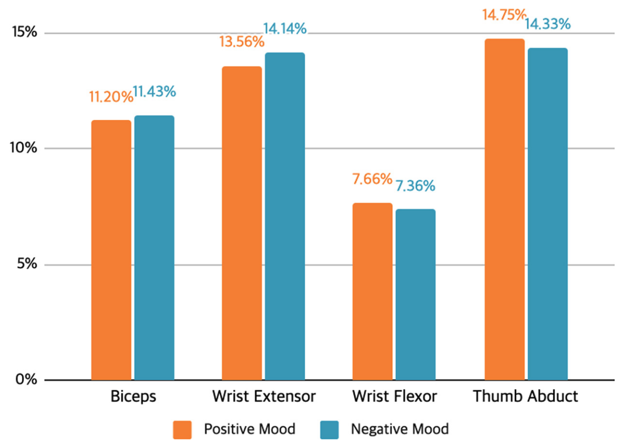

Fig. 6. Mean RMS EMG (%MVC) from four muscle regions

Table 2. Slopes (Hz) of mean frequencies from four muscle region

	Positive Mood		Negative Mood	
	Mean	S.D.	Mean	S.D.
Biceps Brachii	-0.08	±0.08	-0.14	±0.08
Wrist Extensor	-0.02	±0.04	0.03	±0.05
Wrist Flexor	-0.10	±0.07	-0.16	±0.08
Thumb Abductor	-0.02	±0.10	0.18	±0.13

S.D. = Standard Deviation, S = Slopes

Table 3. Slopes (Hz) of mean frequencies from four muscle region

	Positive Mood		Negative Mood	
	Mean	S.D.	Mean	S.D.
Biceps Brachii	-0.06	±0.06	-0.08	±0.05
Wrist Extensor	-0.02	±0.06	0.00	±0.04
Wrist Flexor	-0.04	±0.09	-0.07	±0.09
Thumb Abductor	0.00	±0.15	0.20	±0.14

S.D. = Standard Deviation, S = Slopes

Table 4. Slopes (Hz) of mean frequencies from four muscle region

		Mean Frequency	Median Frequency
Biceps Brachii	Z	-1.48	-.14
	p	0.138	.893
Wrist Extensor	Z	-1.75	-.94
	p	.080	.345
Wrist Flexor	Z	-1.75	-1.21
	p	.080	.225
Thumb Abductor	Z	-2.02	-2.02
	p	.043*	.043*

IV. Discussion

The main objective of this study was to discover possible relationships between personal factor and engagement to a task. Mood was operationalized as personal factor in this study. A hypothetical relationship was derived from the evidence [19] where the authors investigated 823 inpatients with stroke and found that there are positive associations between positive emotion and higher outcomes, such as motor and cognitive status, and functional status quantified with functional independence measure (FIM) [20]. Although they investigated positive emotion, which is a personal factor, the difference between mood and emotion is subtle according to Frijda [21]. Given the similar concept of mood to emotion, mood induction was necessary to test the hypothesis. While there are a number of methods to induce mood, a method known as autobiographical recall was employed to direct effect of participants to positive or negative state since the method has shown to effective for mood induction to test impact of induced mood on evaluative judgement [22] and social judgement [23]. The results of mood induction using the method in this study was consistent with evidence [24] that SAM score for valence was changed to the direction of positive mood or negative mood accordingly. However, arousal was not affected. Although significant change in the level of arousal between positive and negative mood was observed in [25], the findings of a different study confirmed it remained unchanged [26]. Since the inconsistency is not new, this is subject to further investigation.

Apart from the development of rehabilitative interventions, the importance of measurement for engagement is also emphasized. Besides, the number of assessment tool for engagement is increasing [6,7,9]. However, the tools are observational that therapists are required to rate patient engagement during therapeutic session and it needs improvement. In the field of rehabilitation engineering, efforts have been made to measure engagement directly from people who receive rehabilitation therapy. Muscle activity of lower limbs was quantified by EMG during different type of gait training to determine differences in engagement [16]. Relationships between engagement and muscle activities were also investigated in [17]. The authors aimed to assess differences in muscle activities between rehabilitative trainings that requires different level of engagement (bored, normal, and engaged). The level of engagement for the trainings were pre-determined by the authors. They derived normalized EMG by diving RMS of EMG with average velocity of arm motion to test their hypotheses and found increased normalized RMS in engaged level and followed by normal and bored level. We also recorded EMG from four muscle area of non-dominant hand of the research participants. However, we operationalized muscle activities as engagement and investigated them depending on the different mood induced. According to the results of the experiment, there seem to be subtle differences in muscle activities between positive and negative mood. Statistically significant difference was only presented in the muscle activity from wrist extensor. Nevertheless, additional variables computed from EMG signals provided more information. Spectral analysis on EMG signal has been administered. According to a review [18], EMG frequency power spectrum is known to shift to lower frequencies during fatiguing contractions. The slopes computed from the analysis were generally negative value which is expected as the participants were performing the manual dexterity task. Besides, the significant difference in the slope value from thumb abductor and marginally significant difference in the slope values from wrist flexor and wrist extensor can be helpful to differentiate mood states.

Evaluation on the performance of MMDT revealed no significant differences between different states of mood. The occupational therapist analyzed video recordings of arm to quantify errors, which is proportional to completion time of MMDT. The participants dropped the disks randomly meaning that mood may not have impact on the quantity of the disk. This requires further investigations since simply timing the completion time of MMDT is insufficient to address the issues with randomness of dropping the discs.

Although this study explored the relationships between mood and engagement during the administration of a manual dexterity task in healthy people, prior to experimenting in people with medical condition who require rehabilitation therapy, we observed certain trends exist in muscle activities between different states of mood. However, some variables lack in statistical support. Therefore, further research should be followed with the increase in the number of participants. In addition, more features need to be inspected to better understand the subtle differences in engagement caused by a psychological factor.

V. Conclusion

This study has sought the relationships between mood and engagement. It was found that autobiographical recall can successfully induce positive or negative mood. However, it would be difficult to elicit arousal for certain moods. The hypothesis of this study was participants would show different outcomes in rehabilitation task, which would be validated by the different quality of EMG signals, and we learned that EMG signals carry much information. Muscle activities differ between positive mood and negative mood as expected although the outcomes of manual dexterity task between two different moods were not significantly different, and are subjective to further investigation. Therefore, it is limited to prove that EMG signals can be useful to measure patients' engagement in different states of mood. In addition, we experimentally induced mood rather than tested participants with real mood changes. However, the preliminary study results will provide potential opportunity to investigate the influences of mood on rehabilitation engagement with EMG signals among patients in rehabilitation therapy in the future.

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