Pregledni rad
Review

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Stroke Patients' Psychophysiological responses to Robot Training

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Summary

Robotic interfaces are becoming increasingly common in motor rehabilitation, for they enable more intensive therapy. As the patient's cognitive intent further enhances motor relearning, the robots have been usually combined with virtual reality (VR). In clinical environment the difficulty level of the training has to be ensured in a way to meet a particular patient's performance capabilities, inducing appropriate motivation and arousal. While rehabilitation robots can provide objective information about the patient's motor performance and VR-based game systems include real-time feedback, such systems do not offer insight into the patient's psychological state (mood, motivation, engagement). Emotions experienced while playing computer games are reflected in physiological responses, which could be used to determine a patient's level of enjoyment or frustration while training. The most commonly used psychophysiological responses are those of the autonomic nervous system: heart rate, skin conductance, respiration and skin temperature. Though autonomic nervous system responses are also influenced by any physical activity, their usefulness up to a certain level of physical load was confirmed.

Stroke survivors seem to have weaker psychophysiological responses than healthy subjects. The disease itself can change the activity of the autonomic nervous system and other factors such as comorbidity and medication should be taken in consideration to influence psychophysiological measurements. Only skin conductance and skin temperature have been proven to be useful for psychological state estimation in stroke patients during robot-aided training in VR. Changes in heart rate primarily reflect physical activity while changes in respiration rate are small and unreliable.

The psychophysiological measurements seem to be unreliable for assessing stroke patients' psychological state during robot training in VR. Further studies are needed in this aspect of rehabilitation robotics.

Introduction

Our understanding of the neurophysiological processes underlying functional recovery after stroke is evolving. Since cortical reorganization is use- or activity-dependent, modern concepts of motor learning favour repeated practice (1). Motor learning is known to be greater if the practice method is meaningful, repetitive, and intensive (2). For these reasons robotic interfaces are becoming increasingly common in rehabilitation settings, since they enable more intensive therapy (3, 4).

Robotic training offers several potential advantages, including good repeatability, controllable assistance or resistance during movements, and objective and quantifiable measurements of the subject's performance (1). They are frequently combined with virtual reality (VR), computer based technology that also stimulates real-life learning and allows increased intensity of training while providing augmented sensory feedback (5). Feedback of the recorded information via multimodal display technologies consisting of visual, acoustic, and haptic modalities (allowing the patient to move within a virtual environment, manipulate virtual objects, observe the effects of movements and body activity) can motivate the patients to perform the training with maximum effort, endurance and fun. Participants' responses range from unconscious physiological responses (such as electrodermal activity, heart rate and heart rate variability), through automatic behavioural responses, through volitional behavioural responses, emotional and cognitive responses (6).

The difficulty level of the robot training

Though the principle of increased intensive training is widely accepted, there are no clear guidelines for best levels of practice (7). The amount of practice may be the most effective way to improve performance during the training session itself, still it is not optimal for retaining learning over time. A consistent funding in the literature is that introducing frequent and longer rest periods between repetitions and task variability during the sessions improves performance and learning (8).

Thus in clinical environment the difficulty level of the training has to be ensured in a way to meet a particular patient's performance capabilities, to train at optimal-level errors, inducing appropriate motivation and arousal, which are so important for learning (9). While rehabilitation robots can provide objective information about the patient's motor performance, and VR-based game systems engage users in multisensory simulated environments, including real-time feedback, such systems do not offer insight into the patient's psychological state: mood, motivation, engagement, etc.

Psychophysiological responses to robot training

A possible solution to indirectly measure the subject's psychological state would be through psychophysiological measurements. Psychophysiology relies on the assumption that information about a person's psychological state in a particular situation can be obtained from the physiological process (10). Thus the emotions experienced while playing computer games are reflected in physiological responses and this could be used to determine a person's level of enjoyment or frustration while playing. The most commonly used psychophysiological responses are those of the autonomic nervous system: heart rate, respiration, skin conductance and skin temperature. It was shown that heart rate increases and heart rate variability decreases as a response to cognitive workload (11-13). Skin conductance increases with general psychological arousal and cognitive workload (12, 14, 15). Respiratory rate also increases with arousal and cognitive workload (11) while respiratory variability decreases during mentally demanding tasks (16). Skin temperature decreases as a result of cognitive workload (17) as well as a result of tension or anxiety (18).

Monitoring subjects' physiological responses during VR therapy has been used to determine their engagement, their therapy progress and the similarity of VR and real-world therapy. It was found that VR therapy is generally effective (19, 20) and that physiological responses can even be used to gauge effectiveness of the therapy. For instance, skin conductance has shown quick reactions in response to phobic stimuli, but these reactions become smaller over the course of treatment as desensitization occurs (21). Similarly, heart rate has shown differences between phobic and non-phobic subjects in response to phobic stimuli (22).

If we can identify a person's emotions while they are engaged in robot training combined with VR, that information can be used to modify the environment and make the experience more pleasant for the user and the learning process more effective.

Unfortunately, autonomic nervous system responses are not only influenced by a person's psychological state, but also by any physical activity, which is the case in robot training. In spite of that the usefulness of psychophysiological responses up to a certain level of physical load was confirmed (23). Nevertheless, psychophysiological measures respond differently to different types of tasks and they do not always agree with performance or with participants' subjective feelings (6).

Additionally, the disease/injury itself can change the activity of the autonomic nervous system and other factors such as comorbidity and medication should be taken in consideration to influence psychophysiological measurements. For instance, stroke can cause impairments of autonomic control of blood flow and cardiac regulation, specifically if it occurs around parietal and insular cortex (24). In general stroke survivors seem to have weaker psychophysiological responses than healthy subjects, improving somewhat over time (25, 26). Skin conductance and skin temperature have been proven to be the most useful for psychological state estimation in stroke patients during robot-aided training in VR (23). Changes in heart rate primarily reflect physical activity while changes in respiration rate are small and unreliable (23). Correlations between self-report questionnaires and psychophysiological features have found only one correlation in stroke patients and healthy subjects, namely the correlation between skin conductance responses frequency and arousal (26). All this indicates that psychophysiological measurements are not reliable as a primary data source in motor rehabilitation of stroke patients, but can provide only supplementary information (23).

Conclusions

In clinical environments the difficulty level of robot training has to be ensured in a way to meet a particular patient's performance capabilities. Adaptive robot-assistance should continuously adapt to the patient's capabilities during training. If we can identify a person's emotions while he/she is engaged in robot training combined with VR, that information could be used to modify the environment and make the experience more pleasant for the user and the learning process more effective. For the present robotic training offers controllable assistance or resistance during movements, and objective and quantifiable measurements of subject performance, while VR provides augmented sensory feedback. The insight into the patient's psychological state (mood, motivation, engagement) is still lacking. One possibility to indirectly measure the subject's psychological state would be through psychophysiological measurements, however they are not reliable enough for assessing patients' psychological state during robot training in VR. Further studies are needed in this aspect of rehabilitation robotics.

Izjava o sukobu interesa

Autori izjavljuju da nemaju sukob interesa.

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