

Immediate effect of subliminal priming with positive reward stimuli on standing balance in healthy individuals

A randomized controlled trial

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Abstract

Background: Information received subconsciously can influence exercise performance; however, it remains unclear whether subliminal or supraliminal reward is more effective in improving standing balance ability when priming stimuli are subconsciously delivered. The present study aimed to compare the effects of subliminal priming-plus-supraliminal reward stimuli (experimental) with subliminal priming-plus-supraliminal reward stimuli (control) on standing balance ability.

Methods: This was a single-blind (outcome assessor), parallel-group, randomized controlled trial involving healthy young adults recruited from a university in Japan. Assessments were conducted at baseline and immediately after intervention. The primary outcome was the functional reach test (FRT) measurement. The secondary outcome was one-leg standing time (OLST) with eyes closed. Of the 52 participants screened, 25 were randomly assigned to experimental and control groups each.

Results: Both interventions were effective for improving the FRT between the baseline and intervention; however, smaller improvements were observed in the experimental group. We found a large between-groups effect size immediately after the intervention for the FRT ($d = -0.92$). In contrast, there were no differences in improvements in OLST between the 2 groups ($d = -0.06$); furthermore, neither intervention was found to be effective for this parameter.

Conclusion: We concluded that subliminal priming with conscious reward stimuli results in improvements in immediate-term forward reach ability, which is superior to that achieved by subliminal priming with subconscious reward stimuli.

Abbreviations: FRT = functional reach test, LMM = linear mixed models, OLST = one-leg standing time, RCT = randomized controlled trial.

Keywords: postural balance, reward stimuli, subliminal stimulation, unconscious

1. Introduction

Standing balance ability is one of the most necessary physical abilities for humans regardless of age. Standing balance impairment is associated with a lower quality of life in elderly people, stroke patients, and Parkinson's disease patients.^[1-3] Therefore, in a rehabilitation setting, it is important to implement interventions aimed at maintaining and improving this ability.

Several studies have stressed the need for standing balance ability intervention (e.g., exercise interventions^[4-8]) that exists above the threshold of consciousness (i.e., supraliminal). The existing methods of exercise intervention aimed at standing balance ability originally targeted highly motivated and/or well-functioning patients who were able to respond to supraliminal stimulation (including elderly people) (e.g., inclusion criteria: "requiring no walking aid or using a single-point stick only."^[8]) Therefore, it is possible that patients (including elderly people) who were unable to respond to supraliminal stimulation with low motivation to exercise and/or low body function will not adapt to conscious balance exercise. Conversely, subliminal stimulation is an intervention method that may stimulate such patients to participate in standing balance exercises. Subliminal stimulation promotes a desired message in an image at a speed unrecognizable by humans,^[9] which may affect the standing balance ability of humans unconsciously. If this method involving subliminal stimulation creates willingness to exercise in participants by them simply watching a video, this may be a significant step in the promotion of exercise intervention among patients (and elderly people) who are unable to respond to supraliminal stimulation with low motivation and/or low physical function. However, studies that focus on standing balance ability interventions that are delivered on a subconscious level (i.e., subliminal) are rare. One meta-analysis study reported that information presented subconsciously could influence behavior.^[10] Furthermore, this

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intervention may be effective in more than just standing balance. Another study reported that healthy participants who were subliminally primed with the concept of exertion combined with positive supraliminal reward words showed stronger performance on a handgrip activity than those who were only subliminally primed.^[9] In addition, a study reported that subliminal priming, when combined with a supraliminal reward (e.g., nice and great) in the form of a subconsciously visible positive stimulus, significantly increased the handgrip force level of maximum voluntary contraction in healthy individuals.^[11] These results suggested that the intervention that combined subliminal priming with words of encouragement as a supraliminal reward improved exercise performance compared with the intervention with subliminal priming alone. Although, as mentioned above, many studies have investigated the effects of interventions with or without supraliminal rewards, they did not investigate how to supply a reward (supraliminal or subliminal) more effectively. Therefore, it is still unclear whether subliminal or supraliminal reward is more effective in improving standing balance ability when priming stimuli are delivered subconsciously. We hypothesized that subliminal rewards are better than supraliminal rewards considering that the evidence indicates that information presented subconsciously can influence behavior more than information presented consciously can.^[10]

The objective of the present study was to compare the effects of subliminal priming-plus-subliminal reward stimuli and subliminal priming-plus-supraliminal reward stimuli on the standing balance ability of healthy young adults to determine a more efficient intervention method encouraging participation among patients (and elderly people) with low motivation and/or body function.

2. Methods

2.1. Design

This was a single-blind (outcome assessor), parallel-group, randomized controlled trial (RCT) conducted in Japan. The allocation ratio was randomly assigned in a 1:1 ratio to either the experimental group (subliminal priming-plus-subliminal reward) or the control group (subliminal priming-plus-supraliminal reward). This study was approved by the ethics committee of Kibi International University (15–54), and the study was registered at ClinicalTrials.gov (NCT02705092). All participants provided written informed consent. This study followed CONSORT reporting guidelines.^[12]

2.2. Participants

Participants were recruited from Kibi International University, Takahashi, Okayama, Japan, between February 2016 and March 2016. Inclusion criteria were the absence of health-related issues and age of 18 to 24 years. The exclusion criterion was the presence of a physical impairment that hindered performance of daily activities. Participants completed demographic questionnaires (age, sex, height, and exercise habits [presence or absence]) before the intervention. Outcomes were measured at the baseline and immediately after the intervention protocol. We expected an effect size (Cohen *d*) of 0.80 for the primary outcome. At a power level of 0.80 and an alpha level of 0.05, we calculated the sample size per group using *G*Power*.^[13] Assuming equally sized groups, we needed a sample size of 26 per group. We anticipated no loss to follow-up because all measurements were performed on the same day. Therefore, we aimed for a sample size of 26 per group.

2.3. Randomization and blinding

Participants were randomly assigned to the experimental and control groups using computer-generated lists of random numbers via the randomly permuted block method. Baseline and postintervention assessments were performed by outcome assessors who were not involved in the intervention. Throughout the trial, outcome assessors remained blinded to the group status of the participants. Details of group allocation were concealed from participants until the end of the trial. Because of different characteristics of intervention, participants were not blinded to the intervention. The intervention researcher was not blinded to the group status. However, he was not involved in the randomization, intervention allocation, data collection, or statistical analysis.

2.4. Outcome measures

2.4.1. Primary outcomes. The functional reach test (FRT) was performed according to the method described by Duncan et al^[14] using a GB-200 (OG giken, Okayama, Japan). The FRT is used widely as an indicator of forward reach ability,^[14] and the reliability and validity of this test have been established.^[14,15] The FRT evaluates balance while participants stretch out a hand as far as possible with their arms at 90° flexion in a standing position without stepping forward. The primary measure is the difference (in centimeter) between the initial and final hand position in the horizontal plane. The forward reach ability increased in proportion to the increase in the FRT value. The average FRT value of 20- to 40-year-old subjects was 41.8 ± 4.8 cm for males and 32.1 ± 5.5 cm for females.^[14] Measurements were performed twice, and the mean value of the 2 measurements was calculated.

2.4.2. Secondary outcomes. One-leg standing time (OLST) with eyes closed was measured using a stopwatch. The OLST is an indicator of the ability to stand on 1 leg.^[16] It evaluates how long a participant can stand on 1 leg with contralateral hip and knee both flexed at 90° (eyes closed).^[16] Performance time ended when the raised leg touched the floor or until 120 s had elapsed. OLST was measured once on both legs. The increase in the ability to stand on 1 leg was proportional to the increase in the OLST value.

The average OLST value of 20- to 29-year-old subjects was 28.8 ± 2.3 s.^[17] The better score was used for statistical analysis.

2.4.3. Interventions. Participants performed the activities in a quiet room where stimuli were presented on a personal computer with animation (animation of skateboarding) for approximately 2 minutes for both groups.

2.5. Experimental intervention

The experimental intervention consisted of 5 presentations [3 cycles of mosaic visual stimuli (displayed for 117 ms each), physical exertion words as subliminal priming (displayed for 17 ms), and positive words as a subliminal reward (displayed for 17 ms)]. The animation package was displayed 24 times per 5 s for approximately 2 minutes. The experimental intervention procedure is shown in Fig. 1. Physical exertion words (words pertaining to the goal of physical exertion) and positive words were derived from a past study (physical exertion word: “exert”; positive word: “nice”).^[11] The course of experiments is shown in Fig. 2.

2.6. Control intervention

This intervention consisted of 4 presentations (2 cycles of mosaic stimuli [displayed for 117 ms each], physical exertion words as

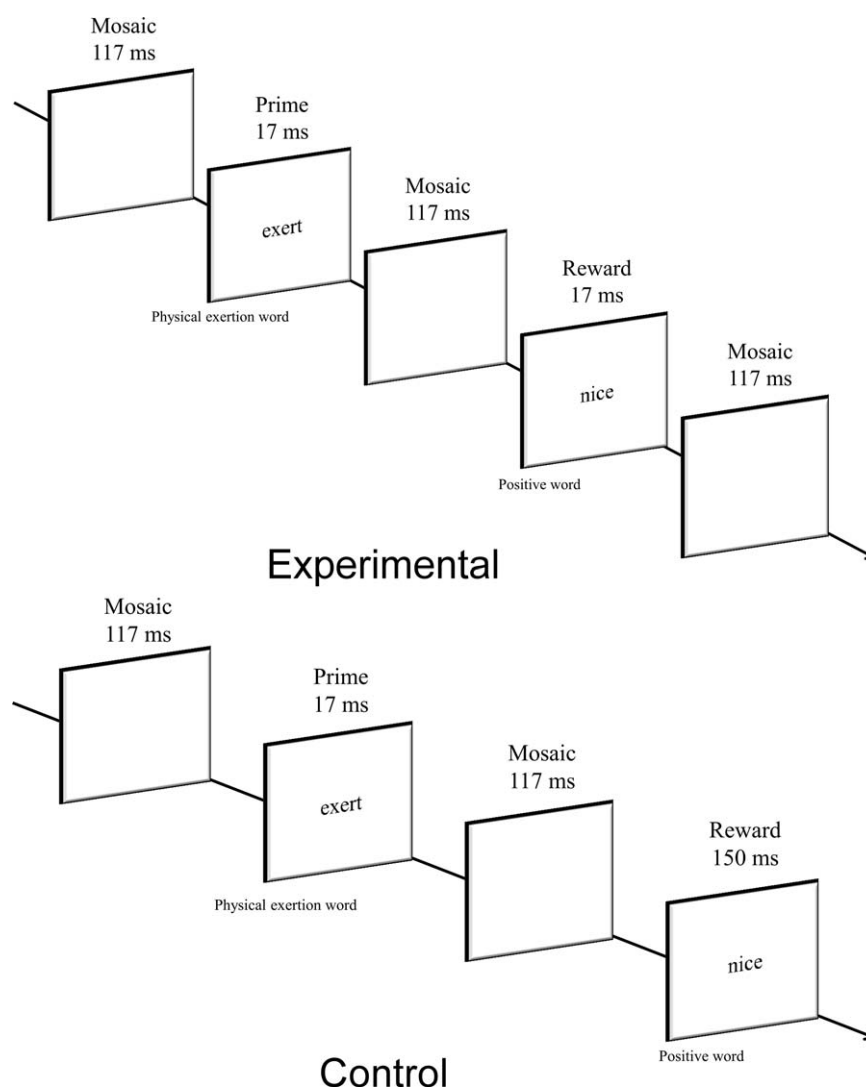


Figure 1. Experimental and control intervention procedure. One animation package (animation of skateboarding) was presented 24 times every 5 s for approximately 2 min. Physical exertion words (words pertaining to the goal of physical exertion) and positive words were based on a previous study (physical exertion word: “exert”; positive word: “nice”).^[11]

subliminal primes [displayed for 17 ms], and positive words as a supraliminal reward [displayed for 150 ms]). As with the experimental intervention, 1 package of animation (animation of skateboarding) was presented 24 times per 5 seconds for approximately 2 minutes. The control intervention procedure is shown in Fig. 1. The physical exertion words, positive words, and animation were the same as those in the experimental intervention. The course of experiments is shown in Fig. 2.

2.7. Statistical analysis

All data were analyzed using SPSS version 23.0. for Windows (IBM, Armonk, NY), and analysis was by intent-to-treat. Baseline characteristics of the groups were compared using Chi square tests for categorical variables and independent *t* tests for continuous variables. Outcomes were analyzed using linear mixed models (LMM) by restricted maximum likelihood estimation.^[18] We included the following as fixed effects: group allocation (experimental or control group), time (baseline or postintervention), and the interaction of group and time. We also

included the participants as a random effect. LMM was used to analyze repeated measures data of previous studies.^[19,20] We statistically analyzed FRT and OLST values at baseline and postintervention for each group using a paired *t*-test. We statistically analyzed FRT and OLST values at postintervention for the experimental and control groups using an independent *t*-test. Effect sizes were calculated as the standardized mean difference (Cohen’s *d*) at postintervention.^[21] Cohen defines effect sizes as small ($d=0.20$), medium ($d=0.50$), and large ($d=0.80$).^[21] In all tests, a 2-sided significance level of <0.05 was used.

3. Results

Between February 2016 and March 2016, 52 participants were assessed for eligibility. Two participants were excluded because of their identified physical disability. In total, 50 met the inclusion criteria and were randomized to either the experimental group ($n=25$) or the control group ($n=25$). All participants received the intervention as allocated. No participants dropped out during the trial. The flow diagram of the process followed throughout this

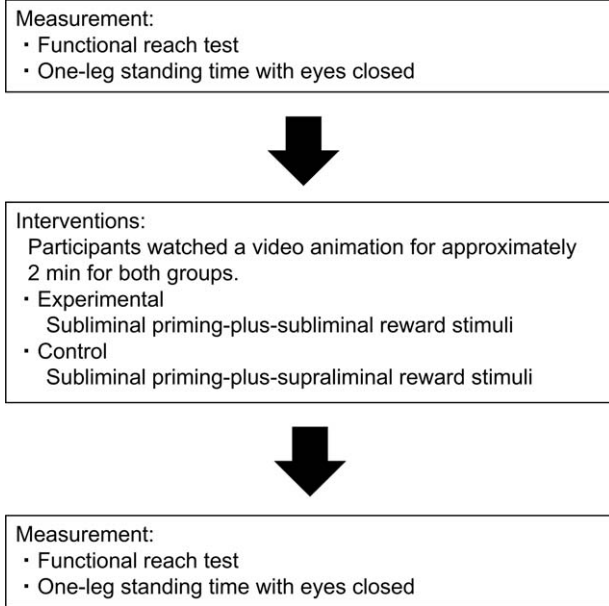


Figure 2. The course of experiments.

Table 1

Baseline characteristics of the 2 groups.

Characteristics	Experimental group (n=25)	Control group (n=25)	P
Age, years	19.04 (0.20)	19.08 (0.76)	.80
Sex, female	8 (32.0%)	9 (36.0%)	.77
Height, cm	166.28 (8.25)	165.24 (8.05)	.65
Exercise habits:			.25
Presence	9 (36.0%)	13 (52.0%)	
Absence	16 (64.0%)	12 (48.0%)	

Data are means (SD) or numbers (%).

demonstrated a significant effect of time on the FRT ($F [1, 48]=34.29; P<.001$) and demonstrated no significant effect of group-by-time interaction on the FRT ($F [1, 48]=3.65; P=.06$). There were significant improvements observed between the baseline and postintervention for both groups on the FRT (experimental: $P=.007$; control: $P<.001$). There was a statistically significant difference between the experimental and control groups at postintervention on the FRT in favor of the control group (mean and 95% confidence interval [CI]; experimental group, 32.30 [30.34–34.26]; control group, 36.71 [34.70–38.72]; $P=.002$). We found a large between-groups effect size at postintervention ($d=-0.92$). The data are summarized in Table 2.

trial is summarized in Fig. 3. Baseline characteristics of the 2 groups are summarized in Table 1. Random assignment successfully produced group equivalence. There were no significant differences in the baseline characteristics of the 2 groups.

3.1. Primary outcomes

3.1.1. FRT. The LMM demonstrated a significant between-groups effect on the FRT ($F [1, 48]=7.09; P=.01$). It

3.2. Secondary outcomes

3.2.1. OLST with eyes closed. The LMM demonstrated no significant between-groups effect on OLST with eyes closed ($F [1, 48]=0.32; P=.58$). It demonstrated no significant effect of time on OLST with eyes closed ($F [1, 48]=1.05; P=.31$) and demonstrated no significant effect of group-by-time interaction on OLST with eyes closed ($F [1, 48]=0.29; P=.60$). There were

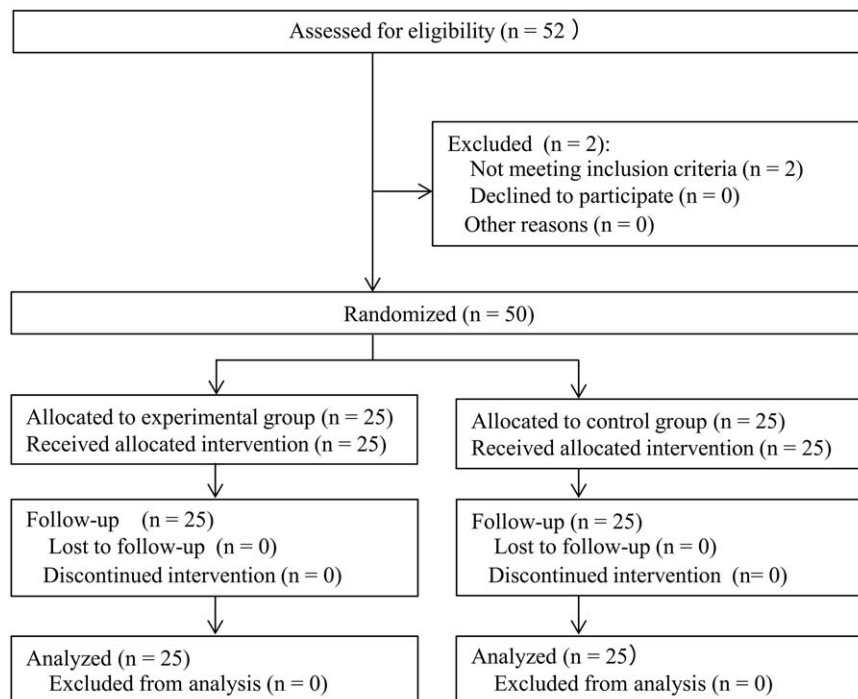


Figure 3. Flow diagram of the processes of this trial for the 2 groups.

Table 2**Results of linear mixed model analysis for experimental and control groups.**

Outcome	Experimental (n=25)			Control (n=25)			Effect size Cohen's <i>d</i>	Linear mixed models			
	Mean	SD	95% CI	Mean	SD	95% CI		Effect	<i>F</i>	<i>df</i>	<i>P</i>
Functional Reach Test, cm											
Baseline	30.64	4.61	28.74–32.54	33.44	5.75	31.07–35.81		Group	7.09	1, 48	.01
Postintervention	32.30	4.74	30.34–34.26	36.71	4.87	34.70–38.72	−0.92	Time	34.29	1, 48	<.001
								G × T	3.65	1, 48	.06
One-leg standing time with eyes closed, s											
Baseline	27.82	28.99	15.85–39.78	34.11	32.03	20.89–47.33		Group	0.32	1, 48	.58
Postintervention	34.67	22.91	25.21–44.13	36.27	31.95	23.08–49.46	−0.06	Time	1.05	1, 48	.31
								G × T	0.29	1, 48	.60

95% CI = 95% confidence intervals, G = group, SD = standard deviations, T = time.

Effect sizes are calculated as standardized mean difference (Cohen's *d*) postintervention.

no significant improvements observed between baseline and postintervention for either group on OLST (experimental: $P = .275$; control: $P = .735$). Furthermore, there was no statistically significant difference between the experimental and control groups at postintervention (mean and 95% CI; experimental group, 34.67 (25.21–44.13); control group, 36.27 (23.08–49.46); $P = .840$, $d = -0.06$). The data are summarized in Table 2.

4. Discussion

The goal of this RCT was to compare 2 interventions, namely (1) subliminal priming-plus-subliminal reward stimuli and (2) subliminal priming-plus-supraliminal reward stimuli, and their effects on standing balance in healthy individuals. On analyzing the primary outcome, contrary to our hypothesis that subliminal reward stimuli would show significantly better improvements on FRT than supraliminal reward stimuli, our results suggested that while both interventions were effective, the supraliminal reward stimuli were actually more effective. A previous study suggested that they have a positive influence on behavior, even if the reward is subliminally primed.^[22] In fact, FRT values improved both before and after the intervention in the experimental group. In other words, our results were consistent with those of the previous research.^[22] However, the control group demonstrated greater improvement than the experiment group. Therefore, supraliminal reward can be considered to be more effective than subliminal reward. Furthermore, although the intervention duration in this study was short (approximately 2 minutes in a day only), it was effective. A further positive effect may be achieved by increasing the number and duration of interventions. Therefore, in addition to other balance practices, regarding the combination of rewards that are presented consciously as shown in the present study, rewards that are presented unconsciously might allow a more efficient approach.

In the secondary outcome, static standing balance in the experimental group (subliminal priming with subliminal reward) did not improve significantly compared with that in the control group (subliminal priming with supraliminal reward). In fact, neither intervention was effective for improving static standing balance from the baseline to immediately after intervention. Although the exact reasons are unknown because this study did not examine this problem, we believe that there is a possibility that the factors influencing the measurement of OLST could not be controlled. For example, 1 study reported that OLST times were significantly shorter when participants had their mouths open than when they were closed.^[23] Participants in our study

were not specifically instructed to have their mouth open or closed during OLST. Therefore, there may have been a large error in the measurement of OLST. Furthermore, the standard deviation is large in the OLST of this study, and there is a possibility that there was a strong influence of individual differences. Therefore, there is a possibility that selecting OLST as an outcome was not optimal.

As mentioned above, in the present study, we did not collect additional outcomes on the mechanism. Therefore, the mechanism of differences between methods of giving reward in this study was inferred from previous studies.

Reward is the enhanced feeling of pleasure, which is the difference between predictive reward and actual reward (i.e., reward prediction error).^[24,25] In other words, because the reward is dependent on consciousness, it is possible to predict reward. Therefore, the effect of subliminal reward stimuli at a subconscious level on reward prediction error is relatively less than that of supraliminal reward stimuli that exist above the threshold of consciousness. In a previous study, it has been suggested that encouragement induces an improvement in walking speed in stroke patients.^[26]

Therefore, in rehabilitation settings, we suggest that therapists should present the reward in a manner in which it can be consciously recognized by patients. However, all these opinions are only speculative because the additional outcome of guessing a reward mechanism was not investigated in this study.

There were several limitations in this study. First, we used a sample of convenience from 1 university, which may not be representative of the entire population of healthy university students. Further studies with random sampling and multi-institutional joint research are needed. Second, this study did not include elderly and disabled participants. Therefore, our results cannot be directly applied to the elderly and disabled populations. Further studies are needed that target elderly and disabled participants needing rehabilitation. Finally, this study only investigated the immediate results of subliminal priming with reward stimuli. Therefore, we cannot make inferences regarding the long-term effects of this method. Further studies with extended follow-up periods are needed to investigate the long-term effects.

5. Conclusion

We found evidence that subliminal priming-plus-supraliminal reward stimuli resulted in significant improvements in immediate-forward reach ability over those achieved by subliminal priming-plus-subliminal reward stimuli. We also found evidence

that both interventions are effective for improving immediate-term forward reach ability. Further studies are needed to investigate the long-term effects.

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