Rhythmic auditory stimulation incorporated in training improved movements in individuals with psychotic-like experiences

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Abstract

Movement abnormalities, including movement slowing and irregular muscle contraction, exist in individuals with psychotic-like experiences (PLEs) and serve as vulnerable factors of developing psychotic diseases in the psychosis continuum. To date scarce studies have developed early intervention programs tackling these initial impairments, which may be caused by basal ganglia alterations, in the early stage of the psychosis course. Rhythmic auditory stimulation (RAS) is a technique of neurological music therapy and has been proved effective in inducing faster movements in patients with psychotic diseases. This pilot study examined if RAS incorporated in functional movement training reduced severity of movement slowing and irregular muscle contraction in individuals with PLEs. Seventeen individuals with PLEs were randomly allocated to receiving RAS or receiving no RAS and underwent daily 40-minute movement training (picking up beans) for three weeks. This study used motion analysis to measure movement performance at pretest and posttest. Eighteen age- and gender-matched individuals without PLEs were also recruited to provide data of intact movements. Results showed that RAS may reduce severity of movement slowing and irregular muscle contraction in individuals with PLEs. This pilot study is one of the pioneering studies validating effectiveness of early intervention programs tackling movement abnormalities, which are initial impairments in the psychosis continuum, in individuals with PLEs.

Keywords: rhythmic auditory stimulation; music therapy; psychotic-like experience; movement abnormality; early intervention; motion analysis

Introduction

Psychotic diseases have been ranked among the most devastating diseases leading to severe distress in individuals during their productive age and causing heavy global burdens [1]. Related symptoms of psychotic diseases encompass psychosis (such as hallucinations and delusions), movement and cognitive abnormalities [2,3]. In order to prevent severe consequences of onset of psychotic diseases, early intervention in the initial stage of the psychosis course has been one of the top goals of psychiatric healthcare [4,5]. Research in the past decades [5-7] has drawn significant attention to the general population who experiences psychotic symptoms (or called psychotic-like experiences; PLEs) in the absence of psychotic diseases. Individuals reporting PLEs have higher risk of developing psychotic diseases afterwards compared with ones without PLEs [8-10]. It will bring substantial benefits to individual life and the healthcare cost to treat impairments in the early psychosis course.

Earlier studies [10-13] have compared group mean values of movement performance, assessed using the Purdue Pegboard test and an instrumental measure (load cells), between the group with PLEs and the group without PLEs (or the healthy control group) and reported group differences. Results [10-13] have indicated that individuals with PLEs have movement abnormalities, including movement slowing and irregular muscle contraction (jerky movements). Individuals reporting PLEs also show poorer social and global functional outcomes than individuals without PLEs [10]. For individuals reporting PLEs, movement abnormalities keep existing from childhood, adolescence, and to early adulthood [10]. Moreover, at the clinical-high-risk stage, which is characterized by considerable distress and high transition rates into psychotic diseases

[14,15], movement abnormalities have also been found [16,17] and even been reported to be indicative of elevated risk of converting to psychotic diseases [18,19]. Accumulating research [3,10,20,21] has suggested that movement abnormalities are trait-like manifestations in the entire psychosis continuum and serve as vulnerable factors of developing psychotic diseases and targets for intervention. Indeed, longitudinal research [10,22] has indicated that reports of PLEs, accompanied by movement abnormalities, in childhood and/or adolescence are associated with poorer psychosocial and global functional outcomes in early adulthood. Consequences of movement abnormalities cannot be overlooked [13] because these deficits extensively interfere with study, work, self-care independence, and social expression. So far, scarce studies have developed movement treatments for individuals with PLEs.

Concurrence of movement abnormalities and PLEs may be explained by basal ganglia alterations in individuals with PLEs [23-25]. Earlier research [23] has indicated group differences in white matter microstructure in striatal areas between individuals with PLEs and ones without PLEs. In addition, it has been reported that individuals with PLEs exhibit increased volumes of the right caudate [25] or decreased volumes of the putamen, caudate, and accumbens [24] than individuals without PLEs. Basal ganglia are important brain regions for coordinating multiple cortical signals, which are sent to and modulated by basal ganglia and then transmitted back to the cortex [26-29]. These cortical signals are involved in human functions of movements, perception, and information processing [26-29]. Therefore, basal ganglia alterations in individuals with PLEs [23-25] may lead to concurrence of movement abnormalities, hallucinations, and delusional ideas.

Given unfavorable side-effects, antipsychotics are not suggested to be the first-line treatment for individuals in the stage before the onset of psychotic diseases [30,31]. Developing effective non-pharmacological intervention for tackling movement abnormalities is certainly warranted in individuals with PLEs. Rhythmic auditory stimulation (RAS), which is incorporated in movement training programs, has high potential to improve movements in individuals with PLEs, who have basal ganglia alterations [23-25]. RAS is provision of beats and tempi of repetitive beep sounds or music [32,33]. Earlier research has demonstrated that suitably faster RAS induces faster movements in people with psychotic diseases [34]. RAS provides external timing cues (i.e., beats and tempi), instead of relying on modulation function of basal ganglia, to guide movement coordination and execution [32,33,35,36]. The neural basis of RAS effects on movement speed and quality is rich and multiple neural connections between auditory and motor cortices in cortical, subcortical, and cerebellar levels in humans [34,37]. Even though basal ganglia are impaired, the auditory cortex activated by RAS is still able to project cues to the motor cortex because of the other rich neural connections [34,37]. To date, no studies have applied RAS to individuals with PLEs and examined if RAS incorporated in movement training improves their movement speed and quality.

To sum up, this study was to examine effects of RAS incorporated in functional movement training on reducing severity of movement slowing (related to movement speed) and irregular muscle contraction (related to movement smoothness and quality) in individuals with PLEs. Because of the subclinical severity of movement abnormalities in individuals with PLEs, traditional observation-based movement scales may not be sensitive enough to detecting changes in movements after training. To overcome this

measurement challenge, this study adopted motion analysis to measure severity of movement slowing and irregular muscle contraction in participants. Motion analysis has been reported to be able to objectively and sensitively detect differences in severity of movement abnormalities between patients with psychotic diseases and healthy people [38], which supported the use of motion analysis in this study. We hypothesized that RAS incorporated in movement training reduced severity of movement slowing and irregular muscle contraction in individuals with PLEs. Results of this pilot study provided initial evidence of effectiveness of an early intervention program targeting movement impairments in the early stage of the psychosis course.

Methods

Participants

Seventeen individuals with PLEs and 18 healthy controls were recruited from secondary schools and universities in Hong Kong. In order to identify individuals with PLEs, we distributed the 16-item Prodromal Questionnaire (PQ-16) [39] and the 15-item Community Assessment of Psychic Experiences (CAPE-15) [40] to secondary schools and universities. Inclusion criteria for individuals with PLEs were a score of or above nine in PQ-16 [39] *or* a score of or above 8.18 in CAPE-15 [40], reflecting a risk of developing psychotic diseases. Other inclusion criteria were aged 13 years or above (considering average age at onset of youth-onset psychotic diseases is around 13 years [41]), a score of or above 22 in the Montreal Cognitive Assessment [42] (showing comprehension of instructions), and a score of or above 60 in the Edinburgh Handedness inventory [43] (indicating right-handed participants). Exclusion criteria, which were

checked via participants' self-report, for individuals with PLEs were diagnoses of psychiatric diseases, taking psychiatric medication, neurological or medical diseases that may affect upper-limb movements.

Inclusion criteria for healthy controls were a score less than nine in PQ-16 [39] *and* a score less than 8.18 in CAPE-15 [40]. Other inclusion criteria were the aforementioned criteria of age, the Montreal Cognitive Assessment [42], and the Edinburgh Handedness inventory [43]. Exclusion criteria, which were also checked via participants' self-report, included all of the above mentioned and first-degree relatives who had psychiatric diseases.

This study obtained ethical approval from the institutional ethical review board of the university (reference number: HSEARS20200630002). All participants signed the informed consent form before joining the study.

Questionnaires for identifying individuals with PLEs

PQ-16 [39] is a 16-item self-report questionnaire for assessing distress severity due to attenuated psychotic symptoms, including hallucinations, delusional ideas, and negative symptoms, in the past month in community people. A higher score means more severe distress due to presence of attenuated psychotic symptoms. This study adopted the Chinese version [39] of PQ-16, indicating that a score of nine or above generates good sensitivity (85%) and specificity (87%) to identify individuals with attenuated psychotic symptoms from the community. PQ-16 has good concurrent validity and test-retest reliability (the intraclass correlation coefficient is .88) [39].

CAPE-15 [40] is a 15-item self-report questionnaire for assessing frequency of lifetime PLEs, including positive and negative psychotic symptoms, and corresponding distress severity in community people. The weighted score of CAPE-15 considers both frequency of and distress due to positive and negative psychotic symptoms. A higher weighted score means more frequent and more distressed PLEs. This study adopted the Chinese version [40] of CAPE-15. The cut-off point for identifying community people with PLEs is 8.18, which has sensitivity of 79% and specificity of 78% [40]. CAPE-15 has good internal consistency (Cronbach's alpha is .88), convergent and divergent validity [40].

Measurement of movement slowing and irregular muscle contraction

A nine-camera optical motion capture system (VICON Vero; Oxford Metrics Inc., Oxford, UK) was used to capture three-dimensional trajectories of reflective markers attached to the participant's right hand when s/he executed the both-hand task. Markers (diameter: 6.3 mm) were attached to the thumb nail and the ulnar styloid process (representing the wrist) of the right hand in the participant. The capture rate of the system was 120 Hz. The MATLAB R2017a (MathWorks, Natick, MA, USA) was used to analyze trajectory data of markers and further compute kinematic variables that represented movement slowing and irregular muscle contraction.

The setup and the procedure of the hand task were described in earlier research [38]. The adaptation of this study was to ask the participant to use both hands simultaneously to execute the hand task, which was more difficult and more sensitive to the subtle movement abnormalities in individuals with PLEs than the one-hand task. At the

beginning of movement measurement, the participant was seated and put both hands at the left and right starting positions on the table respectively (Figure 1). A cylindrical hollow object was positioned in front of the right starting position, and another same object in front of the left starting position. The distance between the starting position and the object on that side was 70% of the arm length in the participant. A pin was fixed on the table and in front of the participant's midline. When hearing the starting beep, the participant was asked to use thumbs and index fingers of both hands simultaneously to reach forward for and pick up the corresponding object, place the left object to the pin, and then place the right object to the pin (Figure 1). The participant needed to execute the entire movement as fast as possible. We collected three movement trials from the participant to calculate the average. The reach-to-grasp movement of the right hand, considering participants were right-handed, was analyzed.

Normalized movement time (nMT) and the normalized number of movement units (nNMU) were calculated to reflect severity of movement slowing and irregular muscle contraction [38,44]. Movement onset timing was when the velocity of the wrist marker achieved 5% of the peak velocity [38,44-47]. Movement end timing was when the velocity of the thumb marker decreased to 0 mm/second [38,45-47]. Movement time, which was the difference between timings of movement onset and end, needed to be normalized (divided) by the participant's arm length because of varying reaching distances on the hand task among all participants [38,44,48]. Larger nMT reflected a slower movement [38,44,48].

A smooth reaching movement includes one acceleration phase, in which the hand continuously accelerated to approach an object, and one deceleration phase, in which

visual inspection is heavily needed to let the hand touch the object precisely [38,44,48]. Therefore, the velocity profile of the smooth reaching movement shows one peak (i.e., one movement unit). Jerky movements during the reaching procedure cause more than one peak in the velocity profile (more jerky movements lead to more peaks in the velocity profile). Similarly, the number of movement units needed to be normalized by the participant's arm length [38,44,48]. Irregular and involuntary muscle contraction causes multiple excess acceleration-deceleration units [11,38]. Larger nNMU reflected less smooth movements and less regular muscle contraction [38,44,48].

Study design

This was a randomized controlled trial (ClinicalTrials.gov registration number: NCT04553835). Individuals with PLEs were randomly assigned to the experimental group, receiving RAS incorporated in functional movement training, or to the control group, receiving functional movement training without the aid of RAS. Sealed opaque envelops were used to determine allocation of groups. Block randomization was adopted to ensure an equal number of individuals with PLEs allocated to each group. The training lasted for 21 days. Pretest was conducted right before the first-day training, and posttest was conducted on the day of or one day after the last-day training. The assessor, who checked if invited participants met inclusion criteria and conducted movement measurement, was blind to group allocation of individuals with PLEs. Healthy controls received one-off movement measurement and did not receive functional movement training and RAS.

Intervention

For the experimental group, individuals with PLEs received RAS incorporated in functional upper-limb movement training. Before the training, research personnel tested baseline performance of the training task without the aid of RAS in each individual with PLEs first in preparation for setting RAS with faster tempi in the next step. Figure 2 shows the setup and procedure of the training task. Three target bowls (diameter: 13.5 cm) with round wooden beans (diameter: 1.5 cm) inside were put in front of the main bowl (diameter: 14.5 cm) at a distance of 30 cm from the main bowl and 30 degrees away from the adjacent target bowl. All bowls adhered to a table mat that showed marks to standardize positions of the bowls. For the training task, the individual with PLEs was asked to hold the main bowl with the left hand and touch the base of the main bowl with the right hand at the beginning. S/he was asked to use the right hand to pick up one bean from the left target bowl, move that bean to the main bowl, repeat the movement for the middle and the right target bowl, and keep repeating the movement cycle from the left, middle, to right target bowl as quickly as possible within 30 seconds. The number of beans successfully put in the main bowl was used to calculate the baseline movement tempo (unit: beats/beans per minute) for the individual with PLEs.

A mobile application, “metronome beats” (the developer: Stonekick in London, UK), was used to generate RAS (repetitive beep sounds) with the required tempo when the individual with PLEs in the experimental group executed the training task. The mobile phone was placed in the lower left corner of the table mat. The individual with PLEs was required to listen to RAS with three tempi (normal, quick, and fast) when executing the training task for 40 minutes per day and a total of 21 consecutive days. The

detailed training protocol and the required tempi of RAS per day in each week were listed in Table 1 and based on the protocol design of the previous typical RAS study [33]. The individual with PLEs needed to pick up one bean in one target bowl when listening to one beep sound of RAS during the movement training. Research personnel provided the 40-minute training session face to face for the individual with PLEs in the university laboratory on the first day of each week (i.e., a total of three face-to-face training sessions) in order to increase RAS tempi and check accuracy of the training procedure. The individual with PLEs listened to RAS and executed the training at home on the other days. Research personnel contacted individuals with PLEs every day to check their compliance with the daily training protocol.

Individuals with PLEs in the control group followed the same 21-day training protocol (daily 40-minute training) without the aid of RAS. During movement training, they were only required to move beans as fast as possible. Similarly, research personnel provided the 40-minute training session face to face for the individual with PLEs in the control group on the first day of each week to check accuracy of the training procedure. Individuals with PLEs executed the training at home on the other days. Research personnel contacted individuals with PLEs every day to check their compliance with the daily training protocol.

Statistical analysis

We used pretest data of individuals with PLEs when we compared performance between individuals with PLEs and healthy controls. The independent-samples *t*-test and the chi-squared test was used to examine differences in nMT and nNMU at pretest as well

as demographic data between individuals with PLEs and healthy controls. In addition, one-way analysis of covariance was used when dependent variables were nMT and nNMU at posttest, the independent variable was the group (individuals with PLEs receiving RAS vs. individuals with PLEs receiving no RAS), and covariates were age, gender, nMT (or nNMU) at pretest, and scores of the Montreal Cognitive Assessment, PQ-16, and CAPE-15. These covariates were chosen because they were potentially associated with dependent variables, regardless of whether there were significant group differences in these variables at pretest/baseline or not. This strategy of considering the association between baseline variables and dependent variables is supported by literature [49]. The alpha level (two-tailed) was 5%.

Results

Demographic data in individuals with PLEs and healthy controls

A total of 17 individuals with PLEs and 18 age- and gender-matched healthy controls were recruited (Table 2; Figure 3). Differences in PQ-16 and CAPE-15 were found between individuals with PLEs and healthy controls. Individuals with PLEs had higher scores in PQ-16 and CAPE-15 than healthy controls. In addition, 17 individuals with PLEs were randomly allocated to receiving RAS incorporated in functional movement training (n = 8) or receiving functional movement training without the aid of RAS (n = 9) (Table 3; Figure 4 and 5).

Differences in movement performance between individuals with PLEs and healthy controls

Differences in nMT and nNMU at pretest were found between individuals with PLEs and healthy controls (Table 2; Figure 3). Individuals with PLEs had larger nMT and nNMU at pretest than healthy controls.

Effects of RAS on movements in individuals with PLEs

Differences in nMT and nNMU at posttest were found between individuals with PLEs receiving RAS and individuals with PLEs receiving no RAS after controlling for potential confounding influences (Table 4). Individuals with PLEs receiving RAS had lower nMT and nNMU at posttest than individuals with PLEs receiving no RAS after confounding effects were controlled.

Discussion

The hypothesis was supported: RAS incorporated in movement training reduced severity of movement slowing and irregular muscle contraction in individuals with PLEs. To our best knowledge, this is the first study to demonstrate that RAS was useful for relieving initial impairments (movement abnormalities) in the early stage of the psychosis course.

The results of slow and jerky movements in individuals with PLEs are consistent with earlier studies [10-13]. Earlier research [19,50,51] has proposed that abnormal basal ganglia play a crucial role in explaining concurrence of diverse abnormalities, including movement abnormalities, hallucinations, and delusions, in the psychosis course. Multiple cortical areas, including the motor cortex and other cortices related to sensory and information processing, send signals to basal ganglia, which regulate these signals and then send the modulated signals back to the cortical areas [26,27]. Individuals with PLEs

have basal ganglia alterations [23-25], which may adversely affect motor and other various functions and lead to movement abnormalities in individuals with PLEs.

For movement slowing and irregular muscle contraction in individuals with PLEs, RAS incorporated in movement training reduced severity of these movement abnormalities, which is consistent with earlier research [34] indicating immediate effects of RAS on movement speed in people with psychotic diseases. This study extends earlier results by showing that the RAS may be effective in reducing severity of movement slowing and irregular muscle contraction in individuals with PLEs. Plentiful neural pathways directly in the cortex and passing basal ganglia connect the auditory cortex and the motor cortex in humans [34,37]. It has been reported that when an examinee listened to RAS but stayed stationary, the motor cortex not only was activated as well [52,53], but also showed synchronization of its neuronal firing and neuronal firing in the auditory cortex in response to RAS [54]. It is also well noted [32,36,37] that humans show a natural tendency to follow the beat, like a cue or anchor, of repetitive sounds or music to make movements. The strong bond between auditory and motor cortices [34,37] explains powerful influences of RAS, acting on the auditory cortex and further affecting the motor cortex, on movement formation. Individuals with PLEs are unable to generate efficient and smooth movements (i.e., existence of movement slowing and irregular muscle contraction) [10-13], which may be caused by basal ganglia alterations [23-25]. Nevertheless, RAS was still likely to provide cues and help regulate signals in the motor cortex in individuals with PLEs because of rich and multiple neural connections between auditory and motor cortices [34,37], thus reducing severity of movement slowing and irregular muscle contraction.

Several limitations should be noted in this study. First, although this study under the current sample size has showed effects of RAS on reducing severity of movement slowing and irregular muscle contraction, the relatively small sample size restricted generalizability of the study findings. Replication of this study in other samples with PLEs with a larger sample size is needed in future research. Second, this study did not examine effects of RAS on ameliorating the psychosis course at long-term follow-ups in individuals with PLEs. Longitudinal observations on individuals with PLEs after provision of movement training involving RAS should be made in order to examine effects of RAS on prevention of a worsening psychosis course. Third, this study did not detect neural changes in the motor cortex, the auditory cortex, and basal ganglia in response to RAS incorporated in movement training. Neuroimaging studies examining brain responses to RAS incorporated in movement training in individuals with PLEs will be warranted to explore or validate neural mechanisms of RAS effects on relieving movement impairments and potentially ameliorating the psychosis course. Last, this study used motion analysis to sensitively provide data of continuous variables to measure severity of movement slowing and irregular muscle contraction in participants. These continuous variable data supported us to detect mean score differences between the group with PLEs and the group without PLEs. Future research is suggested to combine sensitive rating scales or provide cut-off scores of continuous variable values to define presence of movement abnormalities and to calculate the percentage of participants showing movement abnormalities before and after intervention.

Conclusions

This pilot study demonstrated that RAS, a technique of neurological music therapy, incorporated in movement training may reduce severity of movement slowing and irregular muscle contraction in individuals with PLEs. This study is one of the pioneering studies validating effectiveness of non-pharmacological early intervention programs tackling movement abnormalities, which are initial impairments in the psychosis continuum [10-13], in individuals with PLEs. When early intervention for movement impairments in individuals with PLEs is the focus of psychiatric service, healthcare practitioners are suggested to consider using RAS in movement training programs. Future research adopting a large sample size, making follow-up observations, and conducting neuroimaging analysis is warranted.

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Conflict of interest

None

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Author contributions

SMW contributed to conceptualization, methodology, data analysis, and writing of the first draft. STC and YLW contributed to methodology and data analysis. HMH contributed to designing the task used in motion analysis and writing the Matlab program. CYL contributed to methodology and data analysis. CYC and CKL contributed to data processing and data analysis. All authors contributed to manuscript reviewing.

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Figure legends

Fig. 1 The movement task used during motion analysis. (A) When hearing the starting beep, the participant moved both hands from the starting positions and used thumbs and index fingers of both hands simultaneously to reach for and grasp the corresponding object ("the reach-to-grasp movement"). (B) The participant placed the left object to the pin, and then placed the right object to the pin.

Fig. 2 The training task. (A) The setup; (B) at the beginning of the task; and (C) during the training task when the individual with PLEs used the right hand to pick up one bean from one target bowl and then move the bean to the main bowl. PLEs, psychotic-like experiences

Fig. 3 Boxplots of (A) pretest nMT and (B) pretest nNMU for healthy controls and individuals with PLEs. The boxplot shows a median (the thick line within the box), 1st and 3rd quartiles (box bounds), ranges (whisker ends), outliers ("○"; outside 1.5 × the interquartile range from box bounds), and extreme values ("✶"; outside 3 × the interquartile range from box bounds). nMT, the normalized movement time; nNMU, the normalized number of movement units; PLEs, psychotic-like experiences

Fig. 4 Boxplots of (A) nMT and (B) nNMU at pretest and posttest for individuals with PLEs who received training with or without the aid of RAS. The boxplot shows a median (the thick line within the box), 1st and 3rd quartiles (box bounds), ranges (whisker ends), and outliers ("○"; outside 1.5 × the interquartile range from box bounds). nMT, the normalized movement time; nNMU, the normalized number of movement units; PLEs, psychotic-like experiences; RAS, rhythmic auditory stimulation

Fig. 5 The flow diagram of the randomized controlled trial for individuals with PLEs. PLEs, psychotic-like experiences; RAS, rhythmic auditory stimulation; ANCOVA, analysis of covariance; PQ-16, the 16-item Prodromal Questionnaire

Table 1 The daily 40-minute training protocol with required tempi of RAS for a total of 21 days for individuals with PLEs in the experimental group

Day	The RAS tempo (% of the baseline tempo): Movement training duration
1-7	1) Normal (100% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes 2) 5-minute break 3) Quick (105% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes 4) 5-minute break 5) Fast (110% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes
8-14	1) Normal (105% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes 2) 5-minute break 3) Quick (110% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes 4) 5-minute break 5) Fast (115% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes
15-21	1) Normal (110% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes 2) 5-minute break 3) Quick (115% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes 4) 5-minute break 5) Fast (120% of baseline tempo): 3 minutes/round x 3 rounds ≈ 10 minutes

RAS, rhythmic auditory stimulation; PLEs, psychotic-like experiences

Table 2 Differences in kinematic performance between individuals with PLEs and matched healthy controls

	Individuals with PLEs (n = 17)	Healthy controls (n = 18)	t	P
	Mean (SD)	Mean (SD)		
Age (years)	20.71 (2.45)	21.22 (4.71)	.41	.685
Education (years)	14.12 (2.26)	13.39 (3.03)	-.80	.428
MoCA scores	28.53 (1.46)	28.06 (1.26)	-1.03	.311
EHI scores	90.59 (10.88)	88.33 (12.95)	-.56	.582
PQ-16	8.25 (5.91)[a]	1.33 (1.41)	-4.57	<.001
CAPE-15	9.25 (1.80)	5.00 (1.24)	-8.17	<.001
nMT	.0015 (.0003)	.0013 (.0001)	-2.64	.014
nNMU	.0033 (.0006)	.0030 (.0003)	-2.38	.024
	% (n)	% (n)	χ^2	P
Female	52.94 (9)	44.44 (8)	.25	.615

PLEs, psychotic-like experiences; MoCA, the Montreal Cognitive Assessment; EHI, the Edinburgh Handedness Inventory; PQ-16, the 16-item Prodromal Questionnaire; CAPE-15, the 15-item Community Assessment of Psychic Experiences; nMT, the normalized movement time; nNMU, the normalized number of movement units

[a]n = 16 due to missing data in one individual

Table 3 Demographic and kinematic data in individuals with PLEs who received training with or without the aid of RAS at pretest

	PLEs-RAS (n = 8)	PLEs-no RAS (n = 9)	U[a]	P[a]
	Mean (SD)	Mean (SD)		
Age (years)	20.20 (1.86)	21.16 (2.91)	27.50	.423
Education (years)	13.88 (1.89)	14.33 (2.65)	29.00	.541
MoCA scores	29.00 (.76)	28.11 (1.83)	45.00	.423
EHI scores	91.25 (6.41)	90.00 (14.14)	32.50	.743
PQ-16	8.88 (5.00)	7.63 (6.99)[b]	35.50	.721
CAPE-15	10.04 (1.53)	8.54 (1.81)	56.00	.059
nMT	.0015 (.0003)	.0015 (.0003)	39.00	.815
nNMU	.0032 (.0007)	.0034 (.0004)	21.00	.167
	% (n)	% (n)	χ^2	P
Female	62.50 (5)	44.44 (4)	.55	.457

PLEs, psychotic-like experiences; RAS, rhythmic auditory stimulation; MoCA, the Montreal Cognitive Assessment; EHI, the Edinburgh Handedness Inventory; PQ-16, the 16-item Prodromal Questionnaire; CAPE-15, the 15-item Community Assessment of Psychic Experiences; nMT, the normalized movement time; nNMU, the normalized number of movement units

[a]Results of the Mann–Whitney U test.

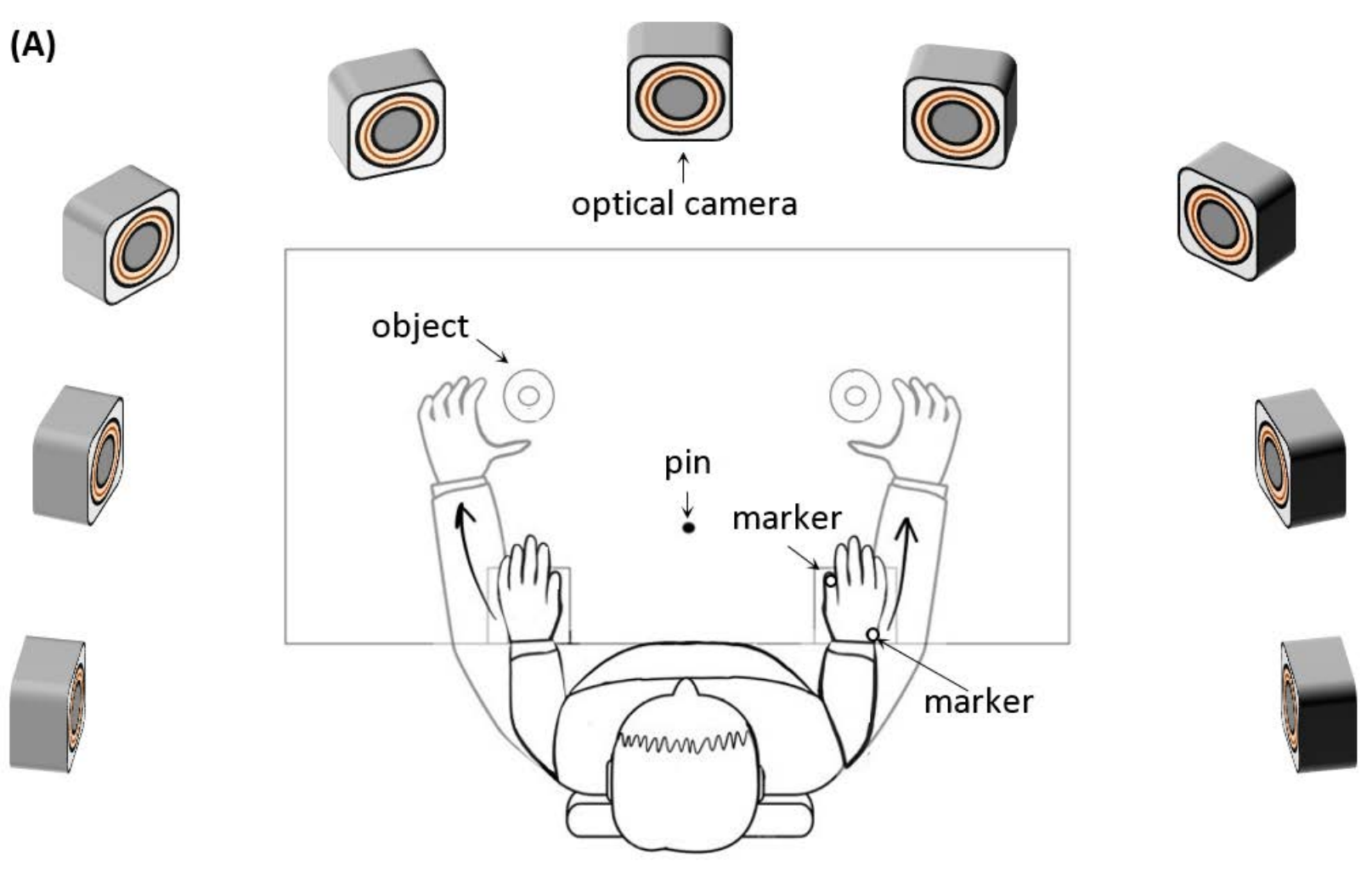
[b]n = 8 due to missing data in one individual with PLEs

Table 4 Results of one-way ANCOVA for kinematic variables at posttest in individuals with PLEs

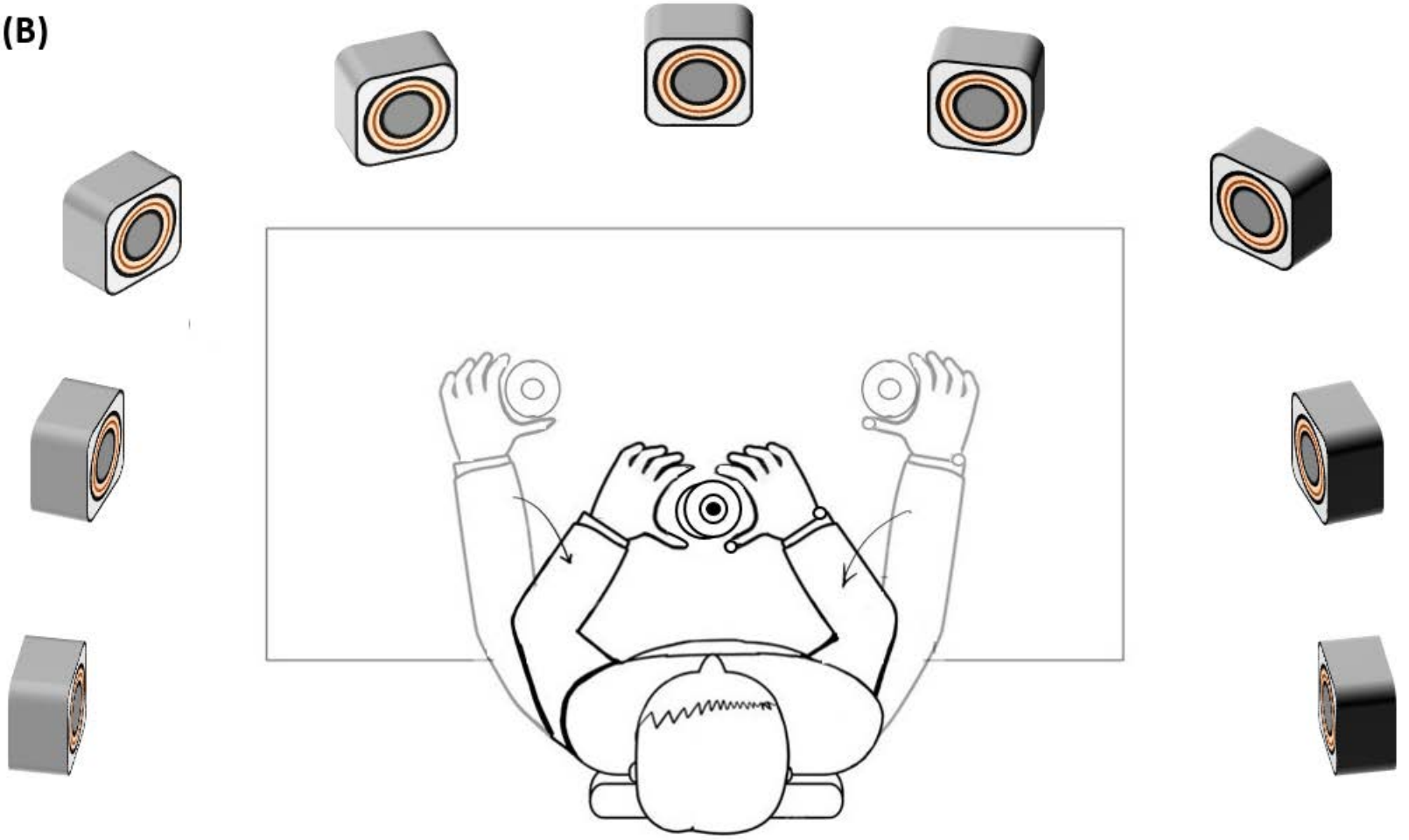
	PLEs-RAS (n = 8)	PLEs-no RAS (n = 8)[a]	F	*P*	Partial η^2
	Mean (SD)	Mean (SD)			
Posttest nMT	.0013 (.0003)	.0014 (.0003)	22.97	.002	.77
Posttest nNMU	.0030 (.0002)	.0044 (.0013)	10.25	.015	.59

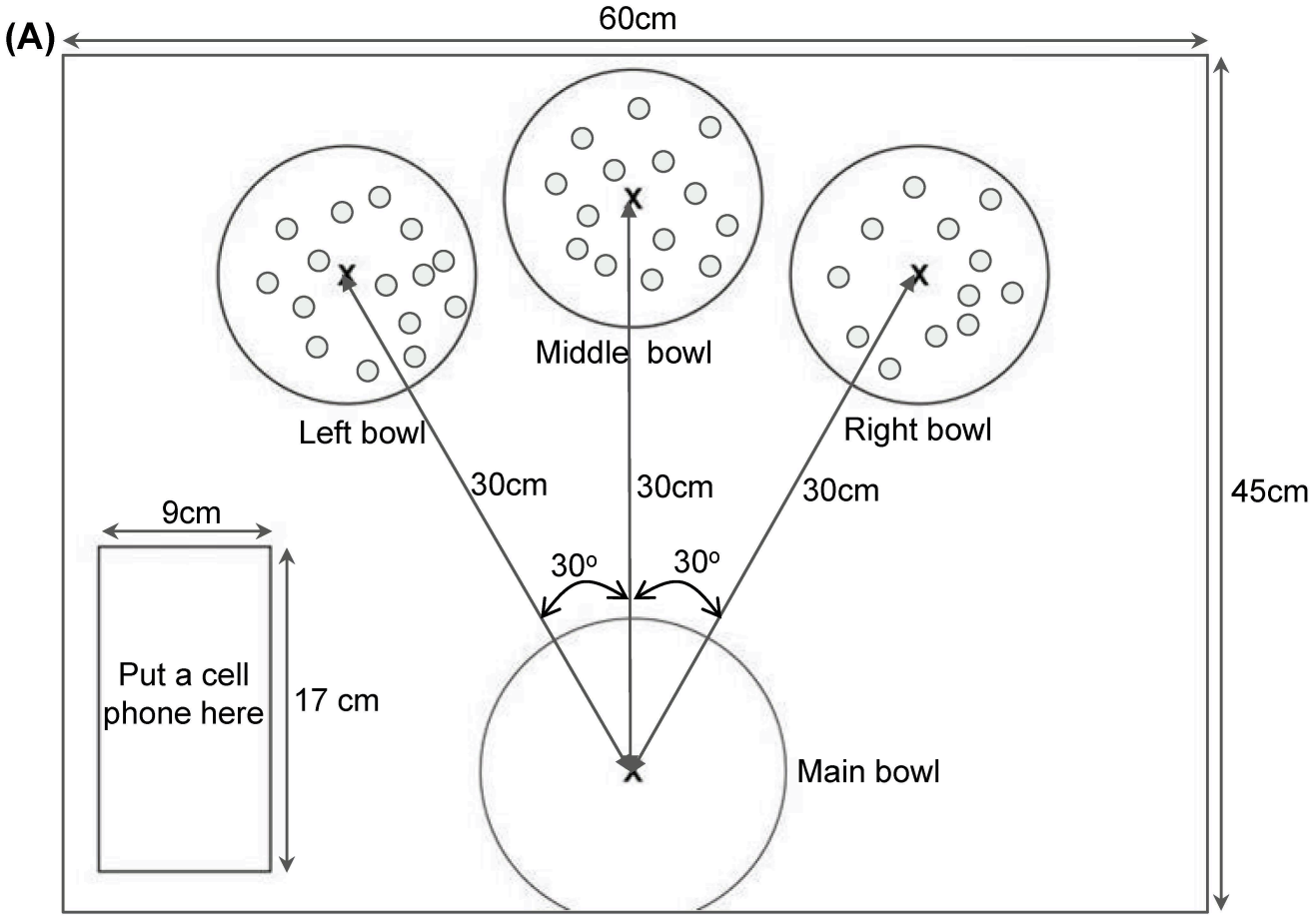
ANCOVA, analysis of covariance; PLEs, psychotic-like experiences; RAS, rhythmic auditory stimulation; nMT, the normalized movement time; nNMU, the normalized number of movement units

[a]Because data of one individual with PLEs who had missing data in the 16-item Prodromal Questionnaire at pretest, as a covariate, were not included in the one-way ANCOVA

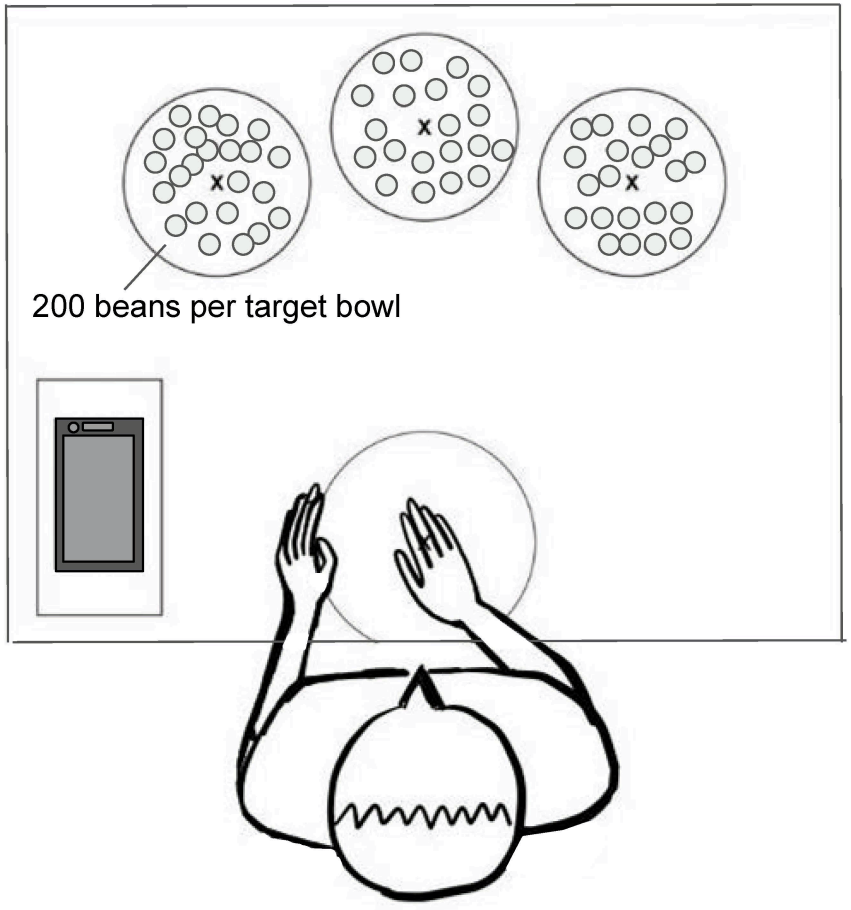

(A)
optical camera
object
pin
marker
marker

(B)




(A)
60cm
45cm
Middle bowl
Left bowl
Right bowl
30cm
30cm
30cm
30°
30°
9cm
17 cm
Put a cell phone here
Main bowl

(B)



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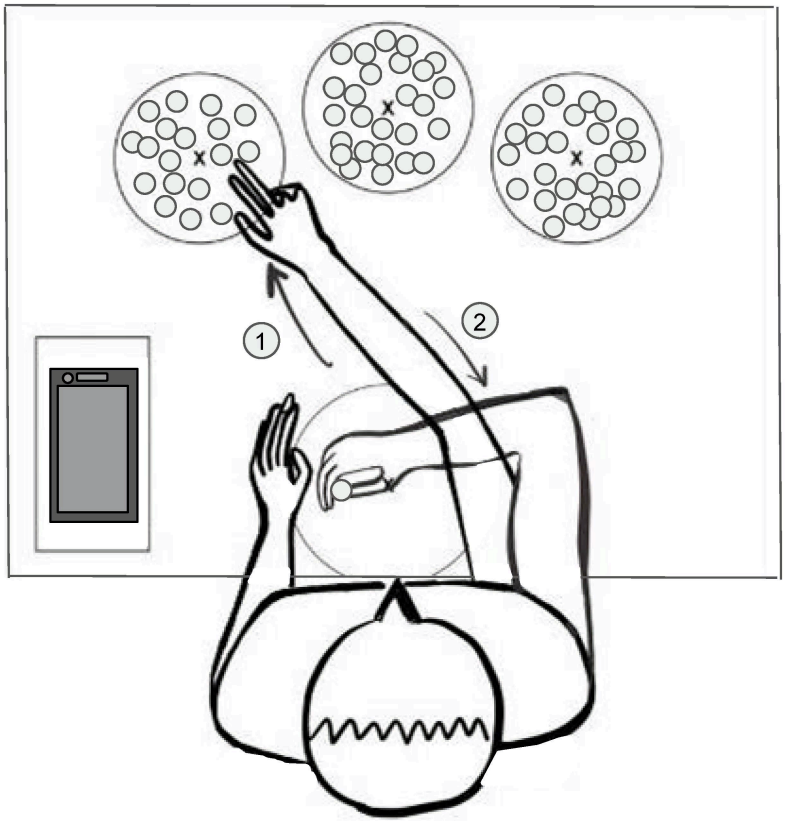

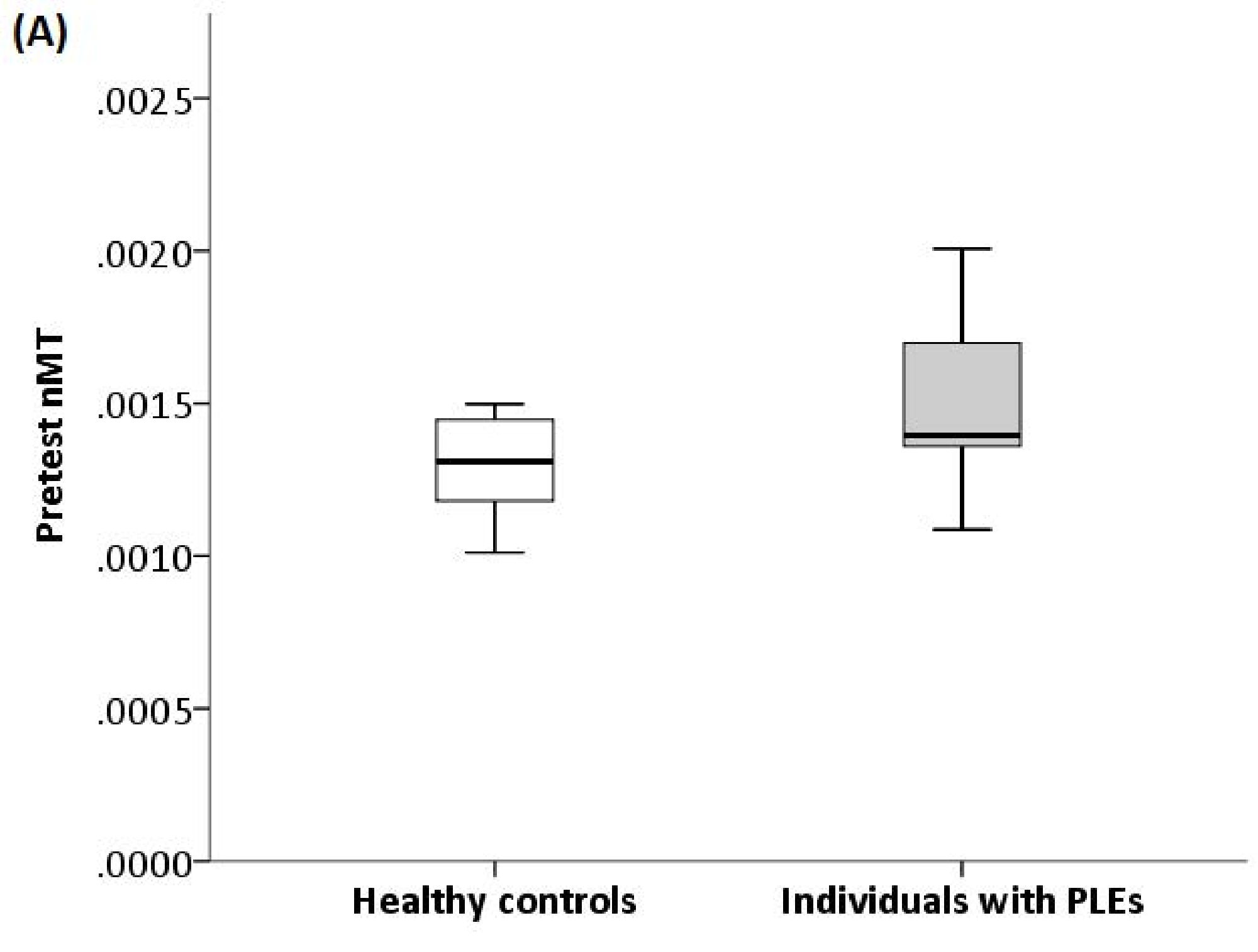
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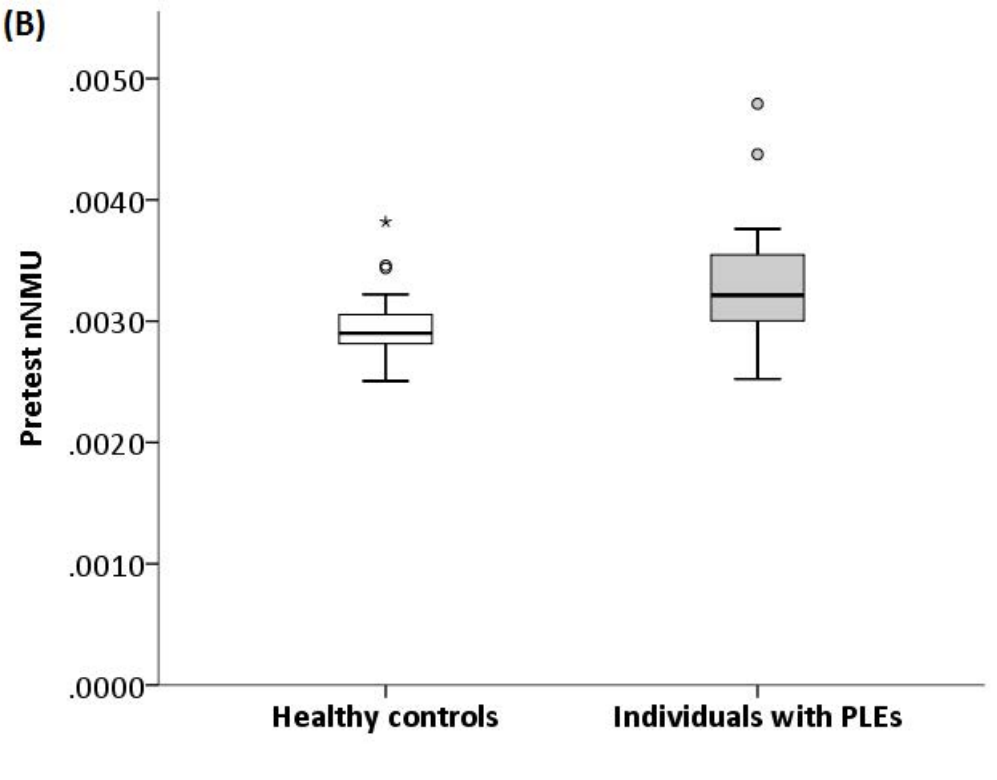
Pretest nMT
Healthy controls
Individuals with PLEs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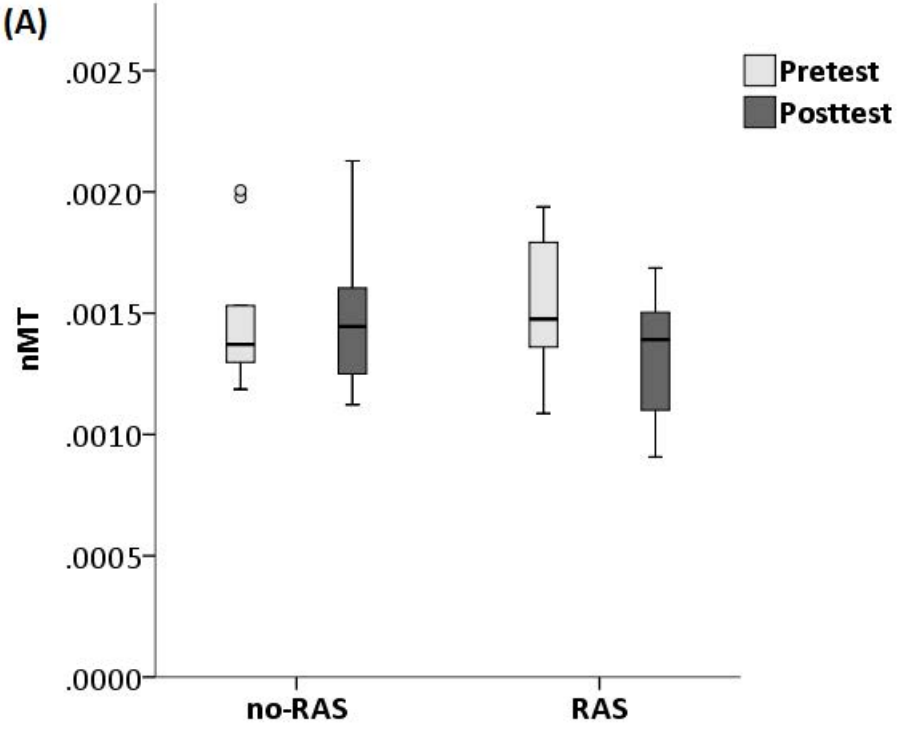
Pretest nNMU
Healthy controls
Individuals with PLEs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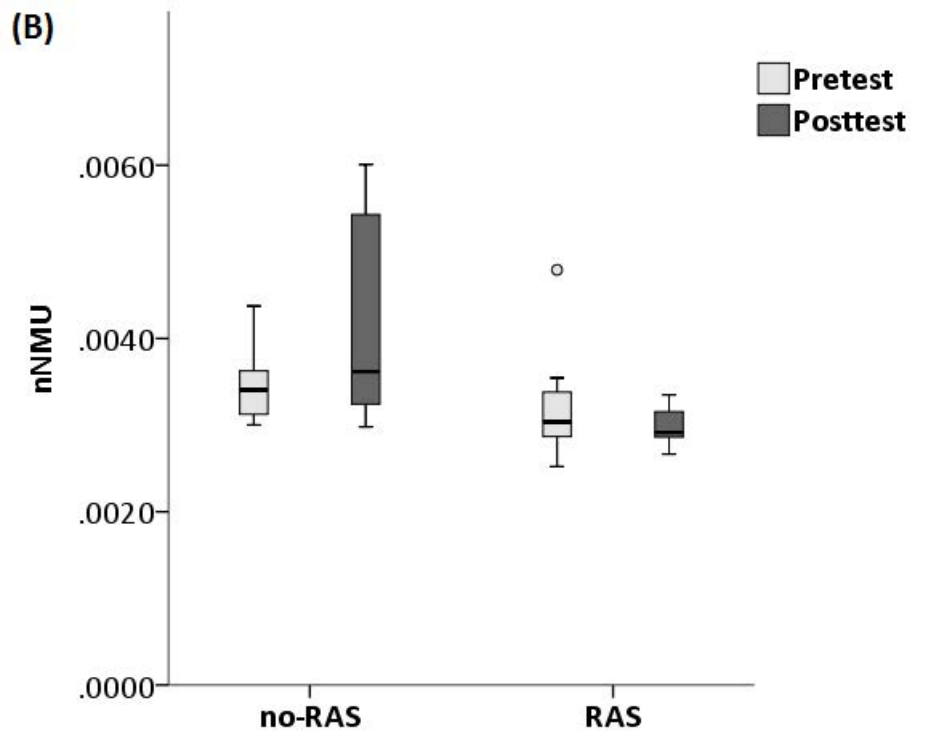
nMT
Pretest
Posttest
no-RAS
RAS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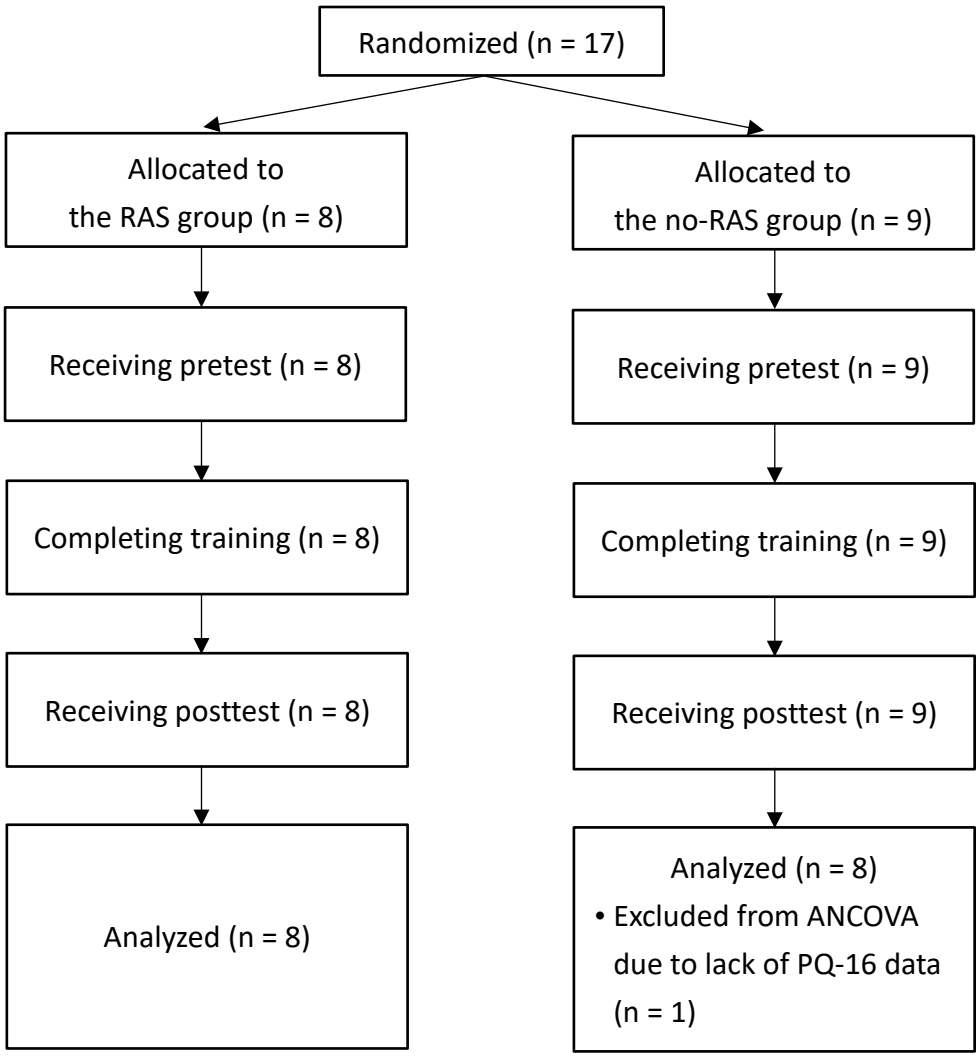
Randomized (n = 17)
Allocated to the RAS group (n = 8)
Allocated to the no-RAS group (n = 9)
Receiving pretest (n = 8)
Receiving pretest (n = 9)
Completing training (n = 8)
Completing training (n = 9)
Receiving posttest (n = 8)
Receiving posttest (n = 9)
Analyzed (n = 8)
Analyzed (n = 8)
• Excluded from ANCOVA due to lack of PQ-16 data (n = 1)