Server-Human Communication in Lucid Dreams

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Summary. **Objective**: This study introduces a proof-of-concept study for connecting people within lucid dreams (LDs) through a specially designed algorithm and an electromyographical (EMG) language. **Method**: Remmyo, an EMG language developed for LDs, was employed to allow the exchange of four randomly generated words. Custom software translated facial electrical impulses into specific sounds, facilitating communication among seven experienced lucid dreamers via earbuds. The server-side algorithm stored messages and automatically delivered them once participants induced LDs. **Results**: Across two experimental nights, the group of seven participants induced a total of 18 LDs verified by polysomnography (PSG), and 14 of which (77%) were registered by a server-side algorithm. Six instances (33%) of server-human communication were achieved, including two delayed transfers between participants. In two cases (11%), participants couldn't correctly repeat the words, while false signals (misperceptions) occurred in four cases (22%). **Discussion**: The analysis of the results showed that the efficiency of the method could be improved by addressing current software-related limitations. This study demonstrates the potential for communication in LDs, paving the way for real-time interactions and new applications. Challenges include addressing false signals that are elements of a dream to ensure accurate communication.

Keywords: Communication, lucid dreams, sleep, REM sleep, electromyography

1. Introduction

In 1913, Dutch physician and writer Frederik Willem van Eeden was the first to use the term lucid dreams (LDs) to refer to dreams in which people are conscious and can follow predetermined goals [1]. Since the 1970s, researchers from around the world have been observing LDs in laboratory conditions [2], [3], [4], and the number of scholarly papers on LD has risen by 5.6% each year from 1966 to 2019 [5]. The topic deserves more attention not only because ordinary people can learn to induce LDs [6] but also because LDs are prevalent—around 55% of people have experienced at least one LD in their lifespan [7]. If representative of the general population, these findings suggest that LDs occur in a significant portion of the human population. If other phenomena similar to LDs are considered (e.g., out-of-body experiences [8], [9], [10], sleep paralysis [11], [12], and false awakenings [13]), their united frequency has been reported to be 88% [14]. Because REM sleep and consciousness are the hallmarks of these states, the umbrella terms *phase state* and *dissociated REM state* can be used to unite them [15], [16].

Further investigation into LDs is warranted due to their potential practical applications. For example, it was shown that LDs may improve motor skills [17], [18] and waking mood [19], [20], [21]. They can also help prevent nightmares [22], [23], solve everyday problems [24], [25], and reduce chronic pain [26] or depression [27]. Moreover, brain-computer interfaces work in LDs [28], and unique music can be created in LDs [18], [29], [30], [31] and transferred into reality in real-time [32]. Two-way interaction with computer programs in real-time is also possible from LDs [33]. LD enthusiasts have reported and discussed many more application directions [34], [35].

It is well established that LDs happen during REM sleep, and only a few verified reports of pre-agreed eye signals detected from non-REM stages contradict this fact [36], [37], [38]. LDs could occur due to increased activity in the parietal lobules, cuneus, bilateral precuneus, prefrontal cortex, and occipito-temporal cortex [39]. It was shown that the connectivity between the temporoparietal junction and the anterior prefrontal cortex plays a role in LDs [40]. The volume of gray matter in the anterior prefrontal cortex has also been observed to influence LDs [41]. Despite these discoveries, in general, the nature of LDs remains unclear [42]. With more progress, an understanding of their nature could lead to advancements in such disciplines as psychology, psychophysiology, physiology, and psychiatry.

Since the 1970s, researchers have attempted to communicate with people in LDs, as doing so could provide a fascinating opportunity to connect the dream world and reality. This achievement could subsequently enhance our knowledge about the brain.

As the first step, it was possible to detect the presence of consciousness in LDs by observing pre-agreed eye movements; this was achieved by Hearne in 1975 using electrooculography (EOG) [4]. In the early 1980s, the same method was widely used by LaBerge, who also proved that conscious signals from LDs could be observed via electromyography (EMG) or breaths. Even though sleep paralysis occurs during REM sleep, it was possible to transmit whole words by Morse signals and EMG [2], [43]. In 2003, Erlacher et al. demonstrated that electroencephalography (EEG) could be deliberately affected by LDs as well [44]. The next step

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was to achieve two-way real-time communication between people in LDs and wakefulness. In 2006, Strelen presented short sine-wave auditory tones at 1000 Hz and 2000 Hz as stimuli, and participants responded selectively [45]. Later, the possibility of two-way communication was confirmed by a few research groups using lights, facial impressions, breaths, and eye movements [46], [47], [48], [49].

Even though Hearne proposed a way to achieve communication in LDs in the 1990s with the help of an automatic telephone dialer triggered by ocular signals [50], actual communication between people in LDs was not achieved due to general complications. For example, all the abovementioned studies faced difficulties in reaching at least one person in an LD. Considering that LDs are often short [10], [51], [52], it is challenging to create laboratory conditions in which two people will be in an LD simultaneously. Another problem has to do with the mode of communication. Even if researchers could speak to a practitioner in LDs using voice, the practitioner would not be able to respond in kind. Alternative methods, such as eye movement or breathing signals, are too limited and impractical to enable full two-way communication between individuals within lucid dreams.

The problem with simultaneous LDs could be temporarily solved by storing messages on servers, similar to communication by mail, email, chats, and so on. As a significant fraction of modern communication happens in these ways, delayed communication in LDs qualifies as communication. Once the possibility of delayed communication has been confirmed, real-time communication in LDs could be more easily achieved.

One way to overcome the limitations with the mode of communication would be to pay attention to facial surface EMG activity during speech. Since the 1980s, many studies have used EMG sensors to decode speech [53], [54]. Great progress has been made in this direction, and more than 90% of words can be recognized using this technique [55]. Such findings are important to the current study, given that facial EMG activity has also been associated with speech in dreams since the 1970s [56], [57], [58]. Moreover, in 2021, it was shown that the phrase *I love you* vocalized in LDs had the same facial EMG pattern as real-life vocalization [59].

Current EMG-based speech recognition technologies can significantly contribute to the study of LDs. However, these methods still face important limitations. First, EMG-based speech recognition in dreams can have a very high error rate due to sleep paralysis, which may considerably decrease the electric activity of some sounds or completely silence them. Therefore, novel studies on speech recognition of known languages in LDs are needed. Second, all EMG-based speech recognition studies have focused on a few specific languages, which could increase the error rate among non-native speakers. According to the abovementioned study on speech recognition for the phrase *I love you*, in LDs, a constructed language based only on EMG distinctive sounds could help unmute people in LDs, as the words could be automatically decoded in reality [59].

A constructed EMG language could solve the two problems noted above and, by providing a common code, might also help reduce language barriers between speakers of different native languages. Moreover, this theoretical language could have high recognition efficiency even in LDs because it could be initially based only on EMG sounds that are distinctive from LDs, meaning that EMG signals avoid the tongue and vocal apparatus.

Remmyo, an EMG language, fits all the requirements mentioned above, as it was deliberately constructed for communication in any phase state, including LDs [60]. In addition to distinctive EMG patterns, people can talk in Remmyo, hear it, and see it through facial expressions while awake (like sign language). The current version of the language has only six letters with paired sounds (consonant+vowel). All the sounds correspond to contractions of specific facial muscles that can be recognized by EMG. However, in a previous study, recognition efficiency varied considerably, ranging from 13% to 81% due to software failures, mispronunciations, and missing sounds [61].

Hypotheses

This study hypothesizes that during LDs, it is feasible to complete a cycle of two-way communication involving all of the following stages:

1. An LD practitioner receives a discrete verbal signal (word), transmitted from the server in a specially constructed EMG language.
2. The LD practitioner responds by accurately reproducing the same word using EMG articulation in the same language. The server receives and stores the EMG-transmitted response.
3. This response is later delivered to another LD practitioner.
4. The second LD practitioner perceives the message and accurately reproduces it.

The successful execution of this full communication cycle would demonstrate that people could communicate while asleep. Validating this proof-of-concept could open new horizons for LD research, foster novel applications and methodologies for sleep and brain researchers, and provide a deeper understanding of the dreaming state and its potential uses. The specific aim of the present study is to test the feasibility of this full communication cycle using an EMG-based language.

2. Methods

2.1. Resources and participants

Due to the large number of participants and limited space in the laboratory, this study was conducted remotely. The participants were sleeping at their homes and their polysomnographic (PSG) data were tracked remotely via servers. This study's ethical approach was approved by the independent members of the Phase Research Center's review board (PRC-2024-07-05-01). Seven highly experienced LD practitioners participated in the study. All of them signed a written informed consent form confirming they were over the age of 18 years and had no health issues that could be triggered by the study. In this study, the participants were financially rewarded only for LDs in which the assigned task was successfully completed. LDs in which the task was not completed were not rewarded. No medical supplements were used for LD induction methods.

2.2. Communication method

Remmyo, an EMG distinctive constructed language, was chosen because a previous study demonstrated its efficiency in LDs [61]. Although it has six sounds/letters and around 200 words, the study was simplified through the use of only the two most basic sounds. The first sound was *k (/kʌ/)*, which is pronounced by opening the mouth and the corresponding natural straining of the *submentalis* area registered by chin EMG, which is standard for PSG recordings. The second was *s (/ʃæ/)*, which is pronounced like a hissing sound without moving the mouth but with an intentional straining of the *frontalis* area registered by the Fpz EEG electrode, which is also standard for PSG recordings (Image 1, 2). The study involved only four possible combinations of these sounds: *kk* ("existing/be"), *ks* (free Remmyo slot used for the word "boost", i.e., a placeholder word with a prearranged meaning that can change from session to session), *ss* ("dot"), and *sk* ("one").

The full Remmyo inventory includes:

- **k** (/kʌ/) – submentalis (chin)
- **s** (/ʃæ/) – frontalis (forehead)
- **l** (/le/) – left zygomaticus major (cheek)
- **c** (/si/) – right zygomaticus major (cheek)
- **b** (/bu:/) – orbicularis oris (lips)
- **h** (/hɨ/) – simultaneous contraction of both zygomaticus muscles

The language omits vowels in writing because each consonant inherently implies a specific vowel based on its articulatory pattern. It follows a subject–verb–object word order, does not use inflections, and contains approximately 200 short, high-frequency words designed for reliable decoding under conditions of sleep paralysis. Remmyo can be spoken, synthesized through software, or perceived visually through facial expressions while awake, functioning similarly to sign language. It was specifically developed for communication during REM-phase states, including LDs [60].

Its viability was previously demonstrated under laboratory conditions, in which four trained LD practitioners attempted to pronounce Remmyo words during 15 verified LDs. EMG decoding accuracy rates ranged from 13% to 81%, with one participant successfully transmitting the word "freedom" in real time 11 times [61]. These results confirmed that Remmyo enables practical, EMG-based communication from within LDs.

A limited number of sounds and combinations were considered because inducing LDs and accurately transmitting even simple EMG signals represented significant challenges without adding complexity to the task. Increasing the number of sounds and the complexity of combinations at this stage could have substantially reduced the likelihood of participants successfully completing the task. The study dealt with transferring information between people in LD but was not concerned with the complexity of this information. Over time and as technology advances, more complex signals and words can be used. Additionally, the sounds *k* and *s* can be easily detected with any standard PSG observation, meaning that the demonstration of communication with these sounds could apply to many other studies because no additional sensors are needed.

Due to Remmyo's distinct pronunciation rules, extensive focus was placed on training volunteers to correctly vocalize the selected words (*kk*, *ks*, *ss*, *sk*). This was crucial, as the words were intended to be articulated during sleep paralysis. Three primary guidelines were emphasized: 1) apply significant strain to the specific target muscle, 2) ensure only the target muscle is activated, and 3) maintain short pauses between letters and longer pauses between words.

2.3. Experimental protocol

First, the participants were thoroughly trained to use the PSG equipment and properly place the EEG, EMG, and EOG electrodes on themselves. Second, participants were to memorize how to pronounce the target Remmyo words, and to verify this, the pronunciation was rehearsed before the experiment. Third, after adjusting the apparatus (the quality of which was checked on the server by the research team), participants were to fall asleep at or close to the same time. Fourth, participants were to induce an LD by any non-pharmacological method. Fifth, after a successful LD entry, the participants were to make at least six distinctive eye movements to the left/right/left side to confirm consciousness in REM sleep, which was automatically detected and verified by the server-side algorithm. These eye movements in LDs needed to be repeated at least once a minute. Sixth, after sending the eye movement signal indicating that they had entered an LD, the participants needed to wait until a random Remmyo word (one of four) was sent to them via earbuds or speakers. The appropriate volume was individually adjusted in advance while participants were awake. When a Remmyo word was heard, participants needed to repeat it. Seventh, if a Remmyo word was sent again, this indicated either that the reproduced word did not correspond to the transmitted one or that an error prevented the server from correctly detecting it. This scenario was repeated until the word reproduced by the participant matched the word transmitted by the server or until the LD ended. Eighth, to validate the result upon awakening, the participants needed to verbally report their LD experiences so they could be compared with the obtained PSG and server data.

2.4. Polysomnography

All participants were monitored in real-time using custom hardware (Image 3) and software. The basic PSG data were recorded with one EEG channel (Fpz and A2 positions of a 10-20 system), one chin EMG channel, and two EOG channels, all equipped with 50-Hz notch filters and appropriate band-pass filters. An additional EMG channel was used to double-check the straining of the *frontalis* area because the *s* sound would be registered only as an artifact on EEG. The server received EMG and EOG signals in real-time, detected LDs by excessive EOG during low chin EMG, and translated EMG signals into Remmyo words. Participants received the sounds via earbuds or speakers near their beds.

2.5. Communication algorithm

A graphical representation of the server algorithm is depicted in Image 4. Its main principles were:

1. Before communication, the participants needed to receive a randomly generated Remmyo word.
2. The server could detect only one of four possible Remmyo words, ignoring all other combinations of *k* and *s*.
3. If a participant could not pronounce any of the four Remmyo words in an LD, the initial randomly generated word given to the first participant was stored and later delivered to the next participant.
4. If a participant mispronounced a Remmyo word, the chat would start from the beginning.
5. If the same participant induced an LD after a successful repetition of a Remmyo word in the previous LD, the server ignored them.

2.6. LD verification

LDs were detected in real time by the server using a custom algorithm that monitored characteristic eye movement patterns corresponding to pre-agreed left-right-left signaling, as well as low chin EMG activity. After the session, all PSG data were manually reviewed and verified by a human rater. REM sleep and pre-agreed eye signals, as core components of LDs, were confirmed using standard procedures based on EOG [2], [4], [62], dominant theta EEG waves and muscle atonia [63]. To indicate the continuation of an LD, participants were instructed to repeat the pre-agreed eye signal sequence periodically, at intervals of several tens of seconds, with each sequence occurring within one minute of the previous one. Participants also provided verbal reports of their LDs and actions to assist the research team in comparing their accounts with the collected data.

3. Results

The experiment took place over two nights, spaced two weeks apart. A total of 18 lucid dreams (LDs) were recorded, with their verification based on pre-agreed eye movements confirmed by PSG. LDs not confirmed by PSG were excluded from the analysis. Eye-movement signals were detected by the server-side algorithm in 14 of 18 LDs (78%). Of these, the server delivered a Remmyo word in 12 cases (67% of 18), whereas two LDs ended prematurely immediately after eye-signal recognition.

Among the 12 LDs with word delivery, three were classified as one-way communication (17% of 18); in these instances, participants perceived the server-delivered word and attempted to reproduce it, which was confirmed by PSG, but the server-side algorithm failed to recognize the articulated Remmyo word. Three cases represented two-way communication (17% of 18), in which the server-delivered word was perceived, correctly reproduced within the LD, and successfully recognized by the server.

Among these six communication events, four (22% of 18) occurred as two successive LD pairs. Each pair constituted a delayed information transfer between participants: one participant's correctly reproduced and server-recognized Remmyo word was stored by the server and subsequently delivered to another participant's later LD.

Table 1. Summary of LD communication outcomes over two experimental nights.

Outcome	Count
Total experimental nights	2
Total LDs confirmed by PSG	18 (100%)
LDs recognized by the server-side algorithm	14 (78%)
LDs with Remmyo word delivery	12 (67%)
Server–participant communication events	6 (33%)
One-way communication events	3 (17%)
Two-way communication events	3 (17%)
Delayed communication events between participants in LDs	2
LDs with false perceptions of sounds or Remmyo words	4 (22%)

Note. Percentages are calculated relative to the total number of LDs (N = 18).

Of the 12 LDs with word delivery, four (22% of 18) involved no perception of sounds. Another four LDs (22% of 18) involved false perceptions of sounds or words that formed part of the dream content but did not correspond to those transmitted by the server-side algorithm. In two of these cases, the LDs were not recognized by the server, and transmission from the server was excluded (Table 1).

First attempt on September 24, 2024

Six of the seven participants took part on the first experimental night of the study. After the PSG set-up and pre-sleep training, all six participants fell asleep around the same time, and five entered LDs. In total, eight LDs were recorded, as confirmed by PSG through pre-agreed eye movements. Of these, the server recognized eye-movement signals in six LDs, and a Remmyo word was delivered in five cases. In these cases, there was one one-way communication event and one two-way communication event; in the remaining cases, participants either reported no perception of sounds, or the LDs ended prematurely. Additionally, one misperception case was recorded, in which the participant reported hearing sounds during the LD that were later identified as part of the dream content and did not correspond to any server transmission. One LD was affected by a server error that prevented a proper response from being detected. A specific sequence of two LDs also provided the first delayed transfer of information between participants: one participant correctly reproduced and transmitted a Remmyo "ss" word ("dot"), which was stored by the server and later delivered to another participant's LD. Subsequent PSG analysis confirmed that the second participant attempted to reproduce the correct answer, but the server mistakenly identified the signal due to the extended duration of one EMG component.

Second attempt on October 8, 2024

On the second night, all seven participants fell asleep around the same time, and they all entered LDs. In total, 10 LDs were recorded, as confirmed by PSG through pre-agreed eye movements. The server recognized eye-movement signals in eight of these LDs, and a Remmyo word was delivered in seven cases. Among these, there were two one-way communication events and two two-way communication events. The two-way events constituted the second delayed inter-participant transfer: the Remmyo "ks" ("boost") word was first correctly reproduced and recognized in one participant's LD, stored by the server, and later delivered to another participant's LD, where it was again correctly reproduced and recognized. In three LDs, participants reported hearing sounds that were later identified as part of the dream content and did not correspond to any server transmission. Two of these misperceptions occurred in LDs not recognized by the server, for which no external transmission was possible. Additionally, one LD was affected by PSG artifacts that led the server to misinterpret the corresponding Remmyo word. In another case, improper EMG articulation prevented correct signal detection (Images 8 and 9).

4. Discussion

To test the proof-of-concept method for automatic server-human and delayed human-human communications in LDs, we used an electromyographical language and a specially developed system, with all inter-participant exchanges mediated by the server-side algorithm. Though the level of success varied, delayed two-way communication between two individuals in LDs was achieved on both experimental nights. While the communication was of the simplest form—limited to the accurate reproduction of single Remmyo words—the outcome fulfilled the primary aim of the study, namely, to demonstrate the feasibility of basic inter-participant exchanges during LDs. This result highlights substantial potential for further studying and applying LDs.

Hypotheses confirmation

Out of 18 PSG-verified LDs, six instances of server–participant communication were achieved (33%), including two cases of the simplest delayed inter-participant communication mediated by the server-side algorithm, which supported the proof-of-concept.

Future implications

If certain issues are resolved, the efficiency of communication between individuals in LDs could be significantly improved. While the concept shows promise, current limitations must be addressed before its real-world applicability can be fully evaluated.

Although the quickest way for humans to absorb information is through vision, verbal language remains one of the most important ways to share information. This highlights the relevance of exploring communication methods in LDs (REM sleep) based on language. Future research may eventually decode any spoken language from dreams, potentially transforming the field of LD research. Until then, viable methods are needed to advance the research, and this study demonstrates that, at present, the Remmyo language can be used to enable basic attempts at communication with dreamers. Currently, Remmyo is the only EMG-distinctive language easily decoded by sensors and software algorithms. Standard PSG sensors could suffice for simple information transfers from LDs, as such sensors align with at least two sounds, namely, *k* and *s* (allowing 12 words of up to three letters, programmable in any meaningful way).

The potential applications of human-server communication include automatic and bidirectional mass studies of REM sleep and various phase states (LDs, sleep paralysis, out-of-body experiences, false awakenings, etc.). This would aid individuals with recurring nightmares and other parasomnias, facilitate communication among LD practitioners, allow information from LDs to be stored, and enable people to receive information and instructions within LDs, among many other applications.

The potential accuracy of communication in LD

PSG data and verbal confirmations revealed 18 LDs of different quality across seven participants over two nights. However, one-way or two-way communication with the server occurred in only six cases (33%). The results may be sufficient for proof-of-concept, but better results could be expected in the best-case scenario in future experiments or the actual implementation of the technology. Below are issues that prevented such a best-case scenario from arising in the present study, as well as possible solutions:

1. Four LDs (22%) were too short, a common issue among LD practitioners that lacks feasible solutions unless new LD techniques are developed.
2. In three cases (17%), participants or the server failed to produce or detect proper eye signals; this issue could be mitigated by a more advanced server algorithm, ideally an AI-based algorithm, capable of identifying LDs more reliably.
3. In one LD (6%), abnormalities in chin EMG activity prevented the server from detecting the LD, although it quickly normalized. This could be resolved by improved algorithms.
4. In one LD (6%), the server did not recognize a Remmyo word; this is a solvable software issue.
5. In another LD (6%), a participant mispronounced a Remmyo word in the LD, which remains a persistent challenge even with training.

Challenge of misperceptions

In 1990, Keith Hearne suggested a method by which individuals could call each other within LDs using a device he had developed, but he also highlighted a key issue: misperception in LDs [50]. This occurred when people sensed electrical impulses from the machine before they were delivered. While it seems that many of the challenges in LD communication could be solved in the near future, misperception is different. The dream world has no boundaries and can simulate any sensory experience, making it difficult to distinguish real external signals from those that are elements of a dream—whether they involve light, sounds, vibrations, or smells. The phenomenon of false awakening, which is common among the general population, is a clear example of the power of misperception in LDs and other phase states [14], [64], [65].

If left unresolved, misperception could undermine the reliability of communication with dream worlds, limiting its potential applications. It is a potential intrinsic limitation that warrants further investigation. Our lab frequently encounters misperception during LD experiments, and it is likely other researchers face similar challenges.

To address this issue, must build on dream incorporation studies, which explore sensory input in dreaming [66], [67], as perhaps only certain perceptions can be accurately mimicked by the brain, while others may be affected relatively little or not at all. Uncommon or rare stimuli could help solve this problem. Alternatively, dreamers could be trained to recognize false signals. We have noticed that misperception often occurs when participants anticipate external stimuli but do not receive them, suggesting that psychological techniques might mitigate its occurrence. Finding a solution to misperception would greatly expand the potential for communication in LDs, unlocking new possibilities for both research and practical applications.

5. Limitations

A few limitations of this study should be discussed. First, even though seven experienced lucid dreamers participated in the experiment, it lasted only two nights due to the study's high complexity and novelty. Two nights could be enough for proof-of-concept studies, but more data are needed to understand the topic better. Only two cases of communication between very talented LD practitioners occurred, even though 18 LDs were reported during the study period. Technical errors played a substantial role, suggesting that communication with servers from within LDs could be an especially challenging issue for less experienced and less trained participants.

A significant portion of the failures happened due to technical errors since the utilized hardware and software are new and complex. Such failures reduce the value of the current study; therefore, resolving them is essential for enabling participants of future studies to achieve significantly better results.

6. Conclusions and Recommendations for Future Studies

We have demonstrated a method to establish human-server and, in its simplest form, delayed human-human communication within LDs. Despite technical limitations, the results demonstrate the feasibility of this approach and indicate its future applicability.

Given that the technology associated with this field is advancing rapidly, researchers should prioritize achieving real-time communication in LDs using similar methods. It is also essential to explore ways to minimize the occurrence of misperceptions.

With sufficient methodological and technical development, this form of communication during REM sleep could open new avenues for LD research and for understanding related phenomena such as sleep paralysis and other parasomnias. Future research in this area must also ensure strict adherence to ethical standards and ongoing discussion within the scientific community and ethical committees.

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Appendix

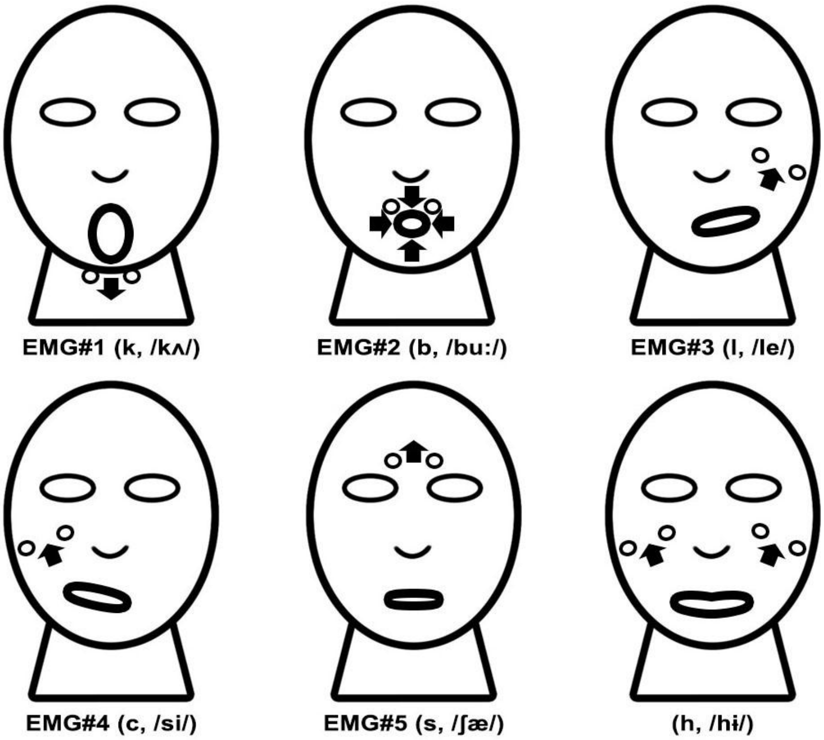

Image 1. Positions of EMG sensors and their relevant Remmyo letters/sounds.

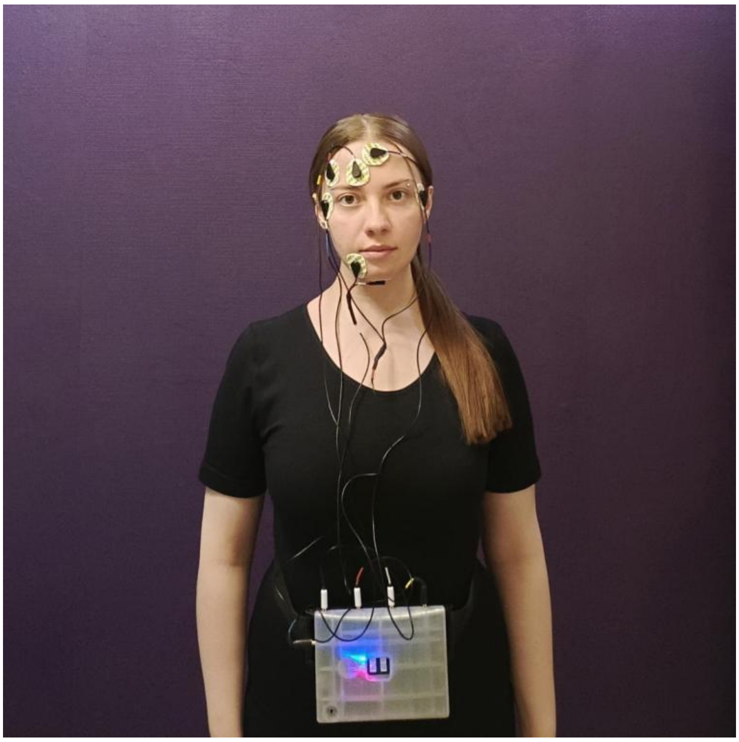

Image 2. Positions of sensors on one of the participants.

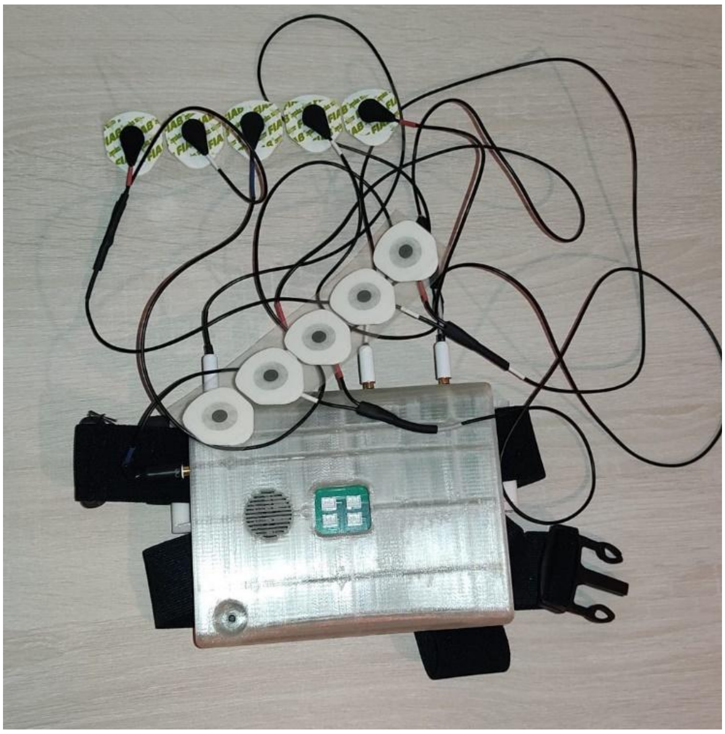

Image 3. Custom hardware with EEG, EOG, and two EMG sensors.

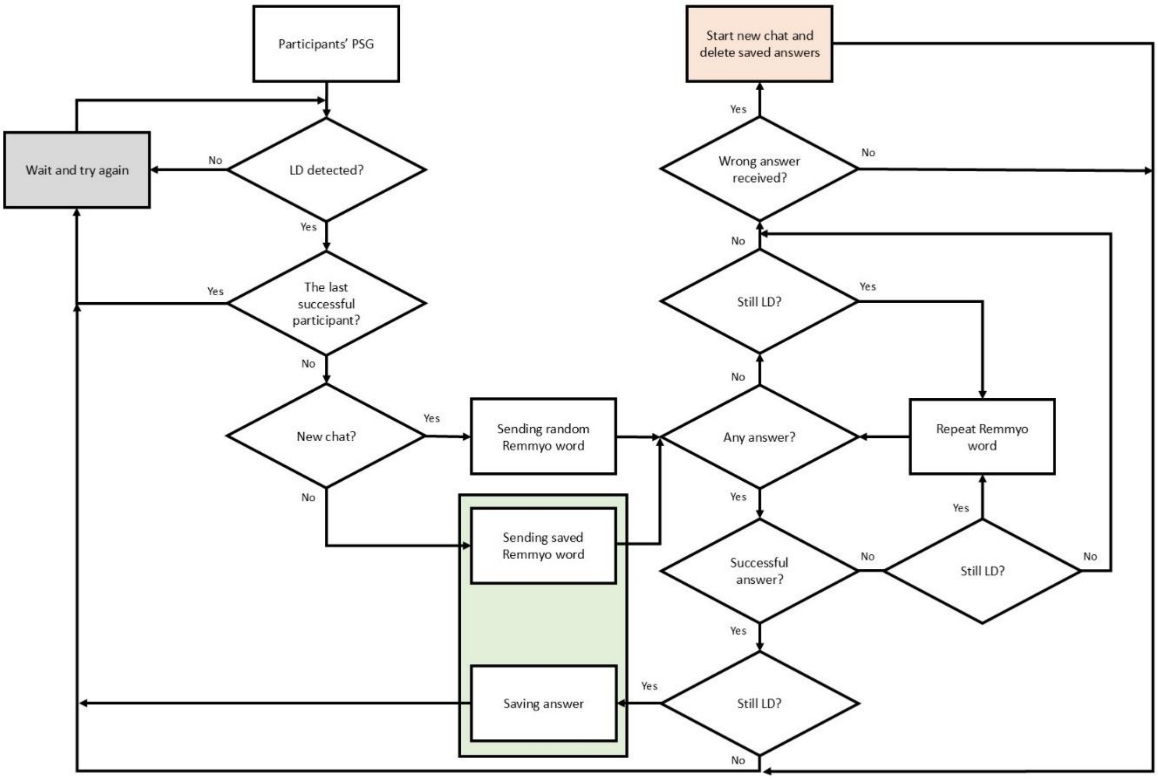

Image 4. Algorithm of the experiment on the server.

Note. Any answer — any spoken word from the four Remmyo options. Successful answer — the word that matched the one transmitted by the server. Wrong answer — a different word from the four options. New chat — a new cycle with a newly generated random word. The last successful participant — a participant who had already reproduced a word correctly in a previous LD; if the same participant entered another LD, they were ignored to ensure transfer between different dreamers.

Image 5. Two participants who communicated with each other in LDs during the first night. Even though there was an 8-minute gap between them, the photos capture the exact moments of communication for each participant.

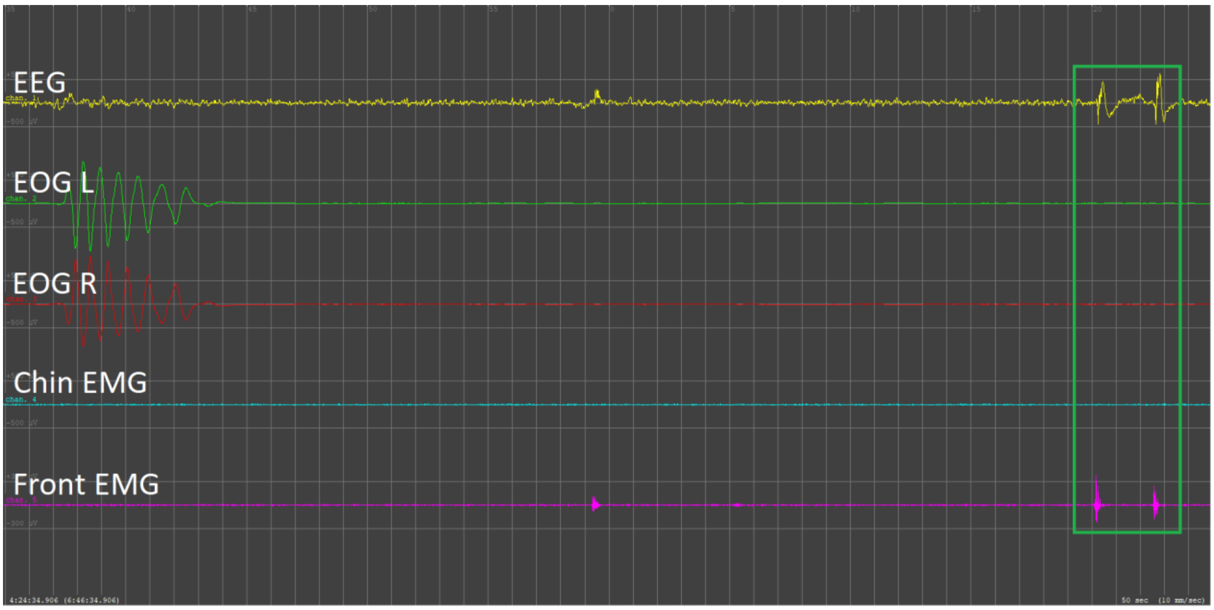

Image 6. PSG data (Epoch – 50 sec) of the first participant who successfully communicated in LDs on the first night. The image represents EEG, EOG, chin EMG, and frontalis EMG (Front EMG). Specific EOG oscillations confirm the presence of consciousness during REM sleep. EEG and Front EMG are responsible for the sound *s*. Two of these sounds together (*ss*) mean "dot."

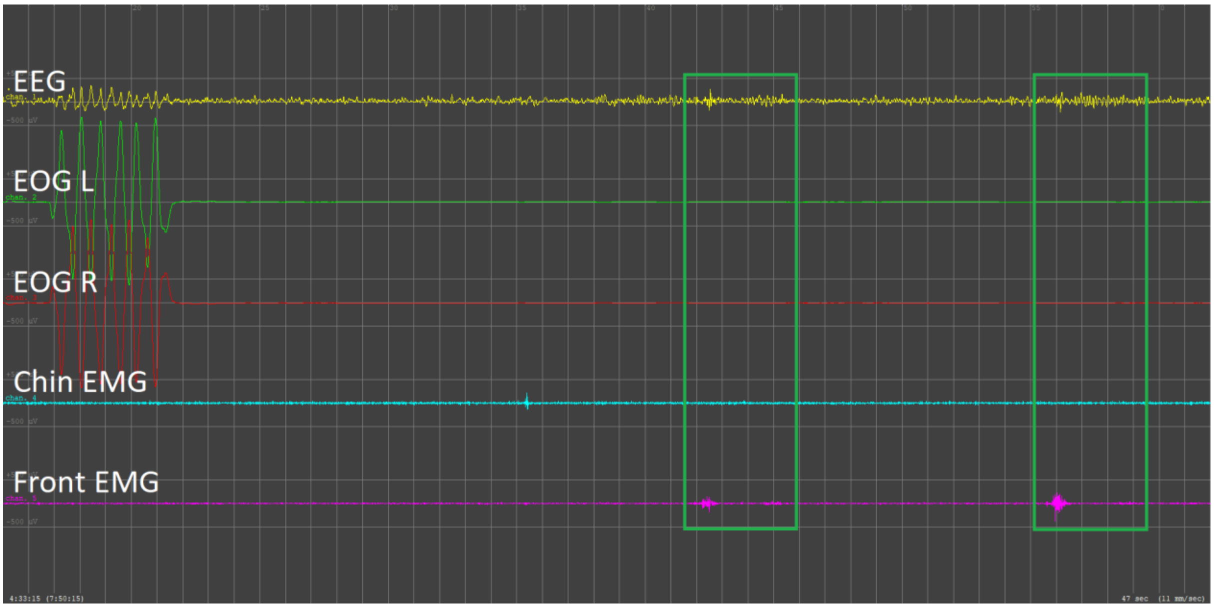

Image 7. PSG data (Epoch – 47 sec) of the second participant who successfully communicated in LDs on the first night. The image represents EEG, EOG, chin EMG, and frontalis EMG (Front EMG). Specific EOG oscillations confirm the presence of consciousness during REM sleep. EEG and Front EMG are responsible for the sound *s*. Two of these sounds together (*ss*) mean "dot," but the participant pronounced only the first letter properly during two consecutive attempts.

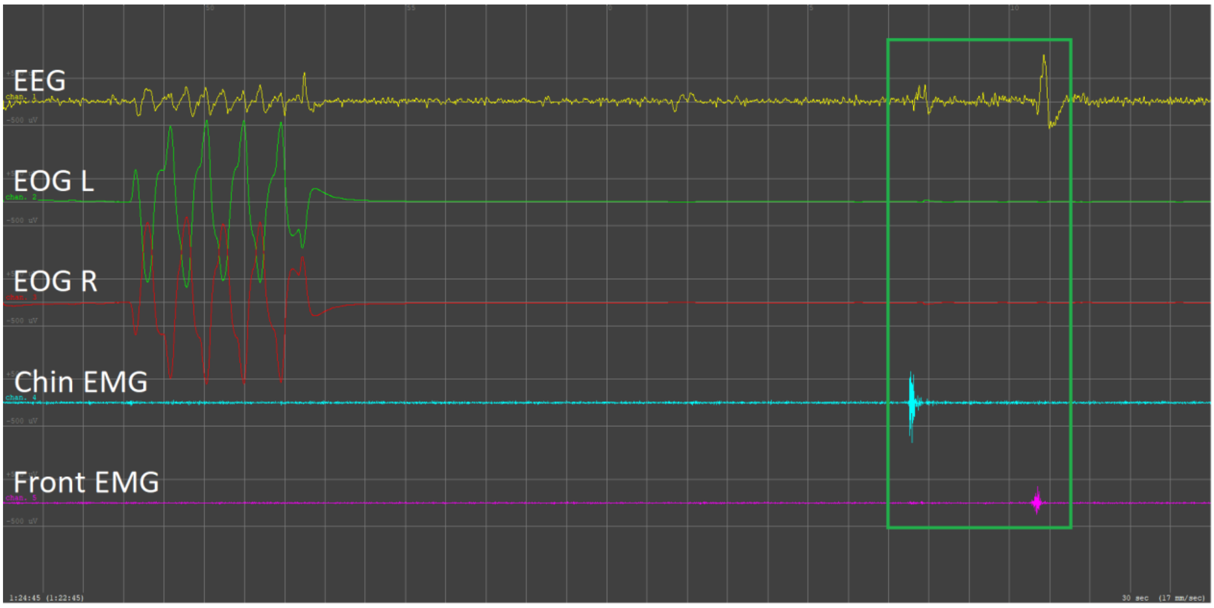

Image 8. PSG data (Epoch – 30 sec) of the first participant who successfully communicated in LDs on the second night. The image represents EEG, EOG, chin EMG, and frontalis EMG (Front EMG). Specific EOG oscillations confirm the presence of consciousness during REM sleep. Chin EMG is responsible for the sound *k*, and EEG and Front EMG are responsible for sound s. These two sounds together (*ks*) meant "boost" on this night.

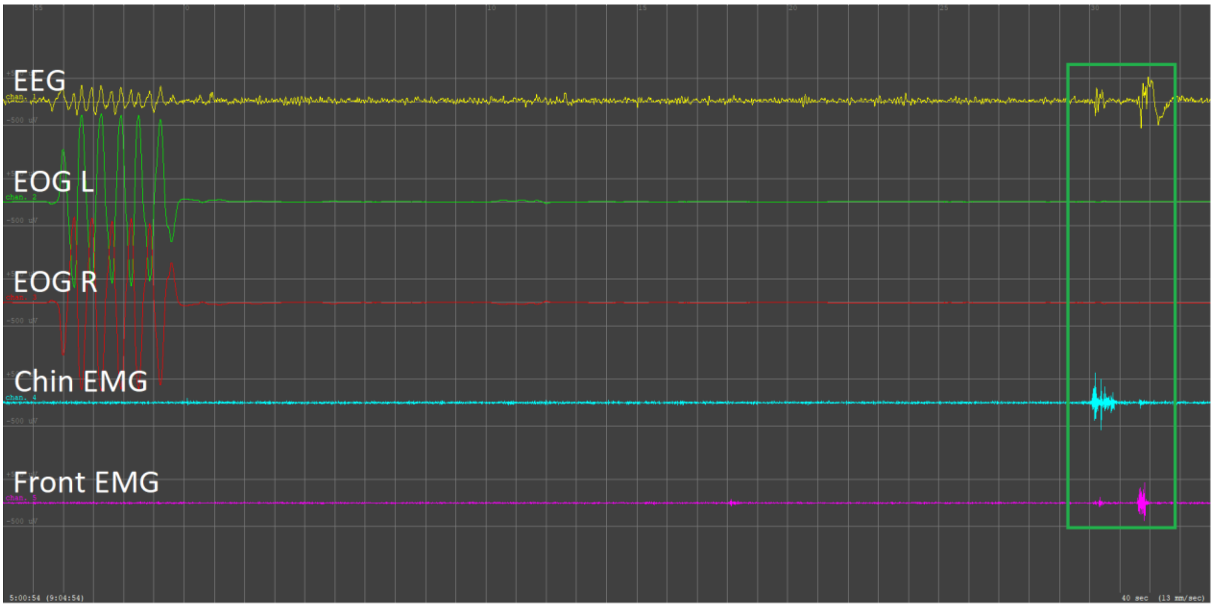

Image 9. PSG data (Epoch – 40 sec) of the second participant who successfully communicated in LDs on the second night. The image represents EEG, EOG, chin EMG, and frontalis EMG (Front EMG). Specific EOG oscillations confirm the presence of consciousness during REM sleep. Chin EMG is responsible for the sound *k*, and EEG and Front EMG are responsible for sound s. These two sounds together (*ks*) meant "boost" on this night.