

BODILY MAPS OF THOUGHT: THOUGHTS CLUSTER IN DIFFERENT PARTS OF THE HEAD

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By
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We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

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M.S. in Neuroscience

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The mind and body are tied together; research on embodied cognition shows that people feel the Self and emotions in the body. They are processed in the mind and perceived through the body template. Building on this notion, we asked whether thoughts are experienced in the body template similarly and whether different kinds of thoughts are located in different bodily regions. In a behavioral experiment, we gave participants short scenarios in five different categories and asked them to imagine/think about those scenarios. Then they were asked to locate their thoughts and images on head and full-body templates. We compared within-category distances to between-category distances, examined each category pair for distinctness, and checked whether any category stood out for being especially tight and consistent. Results showed that people do locate their thoughts on their body template, and different thoughts are located differently from each other. Specifically, thoughts on mental arithmetic and auditory imagery formed distinct groups on the head template compared to other categories. In a second behavioral experiment, we replicated the task with blind and deaf individuals and found that distinct mapping patterns for different thoughts exist in blind individuals, but not in deaf individuals. When compared to other categories, auditory thoughts in blind individuals revealed a very clear and distinct pattern, while visual imagery in deaf individuals showed a distinct localization that differed from other thoughts. Taken together, our findings show that thoughts are located in the body template, with different thoughts located distinctly from each other, and that these localizations are affected by visual and auditory loss.

Keywords: embodied cognition, body template, embodied thoughts.

ÖZET

DÜŞÜNCENİN BEDENSEL HARİTALARI: DÜŞÜNCELER KAFANIN FARKLI BÖLGELERİNDE TOPLANIR

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Zihin ve beden birbirine bağlıdır; bedensel biliş üzerine yapılan araştırmalar, insanların bedenlerinde benliklerini ve duygularını hissettiklerini göstermektedir. Bunlar zihinde işlenir ve beden şablonu aracılığıyla algılanır. Bu kavramdan yola çıkarak, düşüncelerin beden şablonunda benzer şekilde deneyimlenip deneyimlenmediğini ve farklı türdeki düşüncelerin farklı beden bölgelerinde yer alıp almadığını sorguladık. Davranışsal bir deneyde, katılımcılara beş farklı kategoride kısa senaryolar verdik ve bu senaryoları hayal etmelerini/düşünmelerini istedik. Ardından, düşüncelerini ve imgelerini kafa ve tüm vücut şablonlarında konumlandırmalarını istedik. Kategori içi mesafeleri kategori arası mesafelerle karşılaştırdık, her kategori çiftini farklılık açısından inceledik ve herhangi bir kategorinin özellikle sıkı ve tutarlı olmasıyla öne çıkıp çıkmadığını kontrol ettik. Sonuçlar, insanların düşüncelerini vücut şablonunda konumlandırdıklarını ve farklı düşüncelerin birbirinden farklı konumlarda bulunduğunu gösterdi. Özellikle, zihinsel aritmetik ve işitsel imgelerle ilgili düşünceler, diğer kategorilere kıyasla kafa şablonunda farklı gruplar oluşturdu. İkinci bir davranışsal deneyde, bu görevi kör ve sağır bireylerle tekrarladık ve kör bireylerde farklı düşünceler için farklı konumlanma kalıpları olduğunu, ancak sağır bireylerde böyle bir durumun olmadığını gördük. Diğer kategorilerle karşılaştırıldığında, kör bireylerde işitsel düşünceler çok net ve belirgin bir düzen ortaya koyarken, sağır bireylerde görsel imgeler diğer düşüncelerden farklı bir konumlanma gösterdi. Sonuç olarak, bulgularımız düşüncelerin vücut şablonunda yer aldığını, farklı düşüncelerin birbirinden farklı yerlerde konumlandığını ve bu konumlanmaların görme ve işitme kaybından etkilendiğini göstermektedir.

Anahtar sözcükler: bedensel biliş, beden şablonu, bedenlenmiş düşünceler.

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Chapter 1

Introduction

The mind and body are tied together. Cognition, perception, and other mental phenomena—‘products’ of the mind—are embodied. They do not occur in isolation from the body; instead, they occur based on a body template. That is, we have a body template onto which the mind projects its products. Sensations, perceptions, self-awareness, or maybe even thoughts can manifest themselves in this body template in different ways, such as somatosensation or interoception. When we touch something with our fingers, the touch is processed in the brain but perceived at the fingertips. This phenomenon, somatosensation, is the sensory modality that processes our interaction with external stimuli such as touch, pain, and temperature [1]. The rubber hand illusion is a solid example that illustrates the relationship between the mind and the body, employing somatosensation. This illusion helps us understand how the brain constructs and maintains a representation of the body, i.e., how it constructs a body template. It shows that the body template is not fixed but is dynamically updated through multisensory input [2].

In this thesis, we are going to examine how embodiment applies to phenomena beyond the familiar examples, such as touch.

1.1 Perceived Location of Self in The Body

It is accepted rather than questioned that our sense of self is embodied; it is located within our body template. A huge amount of research has been conducted to find evidence of the perceived location of the self within the body template. Most of the results revealed the upper torso (i.e., chest) and the head (specifically, eyes, most of the time) as the ‘seat’ of the subjectively perceived location of the self.

To examine the subjective location of the self within the body, researchers [3] asked participants to identify where they believed the self resided on human silhouettes. The task was then repeated with abstract humanoid figures in which the positions of the eyes, ears, and heart were deliberately changed to assess whether these alterations influenced the location of the Self. On the human silhouette, responses clustered primarily in the brain, followed by the heart; on the abstract figure, selections again concentrated in the brain, with no reliable emphasis on the heart. Moreover, the majority of participants conceived of the self as occupying a single, discrete point rather than being diffusely distributed.

Another experiment [4] investigated where children and adults think their physical selves are located in their bodies. Participants viewed cartoon human figures as well as versions in which the eyes had been relocated to other parts of the cartoon’s body. A stimulus appeared in different areas of the cartoon, and participants were asked when they thought the stimulus was closest to the cartoon. Regardless of the eyes’ placement on the body, responses pointed to the eyes as the locus of the self. The same pattern across both adults and children supports the intuition that the self occupies a precise, single physical position—and that this position corresponds to the eyes.

To obtain an objective measure of the self’s bodily locus, researchers [5] employed the self-prioritization-effect (SPE) paradigm rather than self-judgments of participants used in previous work. Participants completed the SPE task in which they decided which stimulus belonged to them. Only when stimuli were presented to

participants from a point that was close to the head or upper torso, participants showed a more self-prioritization effect, meaning they perceived it closer to themselves and responded accordingly. The study confirmed that the head and upper torso constitute a natural, implicit location of the self.

Building on the previous studies, researchers [6] showed that the self is not located at a single point in the body. In a pointing task in which participants directly pointed at where the conscious self they thought was, they found that the perceived location of the self was distributed across the region between the upper face and the upper torso. They also showed that people's judgments about the self's location shift with contextual cues, specifically, the starting position and direction of the pointer participants used to indicate themselves in this study.

Subsequent work [7] has linked perceived self-location to subjective well-being. In line with earlier results, participants mostly placed the self in the head and chest, but additionally, many identified more than one point in the body as the location of the perceived self. Also, selecting the chest as a locus was positively correlated with psychological well-being, whereas selecting the head showed no such relationship. These data suggest that the felt position of the embodied self may carry implications for well-being besides confirming that the self is embodied mostly in the head and chest.

Similarly, research [8] has explored how perceived self-location influences personality, emotion, decision-making, and performance. In another study, participants selected either the head or the heart as the seat of the self. Heart-locators described themselves as more emotional and warm and exhibited greater emotional reactivity, whereas head-locators portrayed themselves as more rational, logical, and showed higher levels of antisocial tendencies. Building on these results, subsequent work [9] examined interpersonal connectedness: individuals who placed the self in the heart reported stronger emotional warmth and closer ties to both self and others, whereas those who chose the head as the location of the self felt less bonded. Taken together, these findings suggest that the Self is not only embodied in specific locations of the body but also related to differences in emotional style, social orientation, and cognitive approach.

Extending these findings, experiments [10] show that perceived self-location is highly flexible rather than fixed in a single body region. When meditation practice led participants to direct attention to specific bodily areas, the reported seat of the self shifted from the head toward the upper torso and abdomen. This result suggests that self-location can dynamically change in response to factors such as attentional focus.

A daily-experience sampling study [11] indicates that perceived self-location can change from one day to the next, shifting with internal states and daily experiences. During stressful situations and problem-solving episodes, individuals tend to situate the self in the head. On the other hand, those who located the self in their hearts were found to be in a better state of well-being. These patterns imply that where the self is felt in the body both reflects and shapes our perspective on incidents.

Research on digital game design has used embodied self in avatar design. Researchers [12] had participants play with avatars representing themselves and others to observe their responses toward various stimuli in the game. Participants processed their own avatars more efficiently, and the self-prioritization effect was strongest when task stimuli appeared on the avatar's upper torso rather than other body regions. The finding implies that attention is drawn to avatar areas that correspond to where the self is intuitively situated, which is the upper torso.

Taken together, these findings indicate that the embodied self is located mainly in the head and chest, yet it is not fixed at a single spot. Its felt position shifts across experimental paradigms, situational contexts, and individual traits, and can even change from moment to moment within the same person. In other words, the self is a construct of the mind, yet it is experienced as an ever-changing resident within the body.

1.2 Perceived Location of Emotions in the Body

The body and emotions are deeply intertwined and inseparable. As William James said, “For us, emotion dissociated from all bodily feeling is inconceivable.” [13]. Emotion encompasses bodily responses even in its definition [14], showing that bodily components are included in the concept of emotion from the very beginning. We might argue that emotions are innate physiological programs developed to maintain and protect the body’s homeostasis [15]. For this reason, to maintain the body’s harmony and order, emotions are tightly bound to bodily sensations [16]. They, though processed in the mind, reveal themselves in the body. In daily language, we often describe our emotions in terms of bodily metaphors [17]. Anxiety manifests itself in the form of sweaty palms and a racing heart; cold feet are associated with fear, and happiness is felt as butterflies in the stomach. All of this leads us to the point that emotions are, by nature, embodied.

Not only are they embodied, but there is physiological specificity across emotions. Studies show that emotions have distinct localizations in the body. Researchers have worked on topographical maps that reveal the location of emotions in the body. They developed a tool called emBODY[18] that allows people to map the bodily sensations associated with different emotions. Then they recorded different bodily sensations that are associated with emotions in body maps called the bodily sensation maps (BSMs) [18]. People marked the areas of the body where emotions are felt most and least, as well as which parts of the body become more active or less active when experiencing a particular emotion. The results revealed that bodily sensations associated with different emotions are mapped across different parts of the body in distinct patterns. According to the BSMs, anger is most commonly located in the face, chest, and hands; shame is in the cheeks; fear is in the chest; happiness is in the head and chest; and anxiety is prominently located in the chest. Additionally, it has been observed that these topographical maps of bodily sensations are culturally universal [18] .

Following this prominent study in the field, research advanced further on emotions related to bodily sensations and how these bodily sensations are mapped

in the body by individuals. In another study [19], participants were presented with emotional stimuli (anger, fear, disgust, happiness, sadness, and neutral) and instructed to close their eyes for a period of time, and carefully look into their bodily sensations and where their senses come from. They were then asked to report the locations of the sensations in their bodies. The results confirmed the previous findings: Individuals associated different emotional states with distinct patterns of bodily sensations in their bodies. For different emotional states, both common and separate spatial patterns were revealed. The chest was a common area for all emotions. While both anger and fear showed physical sensations in the fists, only anger showed sensations in the lower legs and feet. On the other hand, a specific pattern of physical sensations throughout the gastrointestinal system was only associated with disgust. So, this study provides additional support for specific topographical distributions of bodily sensations for distinct emotional stimuli [19].

Another recent study investigated the bodily representation of emotions in blind individuals [20]. The question was whether a sensory loss (i.e., vision) modifies the way emotions are felt in the body. The researchers asked participants (congenitally blind, late blind, visually impaired individuals, and sighted individuals) to think about an emotion and report in which part of their body they feel physical sensations associated with that specific emotion. The results were in line with previous studies, showing that emotion-body associations are similar irrespective of visual experience. The head was the most common body part associated with anger across all individuals. The face was associated with love the most, and the shoulders were associated with sadness. Arms were reported as the body parts that are associated with anxiety, and hands were associated with envy [20].

Researchers [21] asserted that the classical bodily sensation maps (BSMs) assess only the activity dimension of the emotions (i.e., in which part of the body one feels more or less active when a specific emotion is felt?). However, there was one factor that was overlooked here. In Nummenmaa's study [18], for instance, two different emotions, anger and pride, both showed significant upper body activity in the BSMs, meaning that the BSMs of these two emotions were very similar. However, there was a fundamentally significant difference between

the feelings experienced during these two emotions. Therefore, Hartmann and his colleagues aimed to measure how the valence aspect of emotion is located in the body. According to Hartmann and his colleagues, the most sensible way to measure emotional valence—that is, whether an emotion is pleasant or unpleasant—in terms of bodily sensations was to use the weight metaphor. This is because when we experience pleasant feelings, we describe ourselves as feeling light, while unpleasant feelings are described as feeling heavy. To measure the valence dimension of emotions (i.e., in which part of the body one feels lighter or heavier when a specific emotion is felt?), they developed weight-BSMs. It was found that people felt bodily lightness when happiness, love, and pride were involved, and bodily heaviness when depression and sadness were involved [21]. Happiness felt light in the head and upper body, while love felt light in the head. Depression felt heavy on the head and upper body, while sadness felt heavy on the chest. Thus, just as in Nummenmaa’s classical activity BSMs, weight BSMs also revealed distinct patterns for different emotions. The study showed that the valence aspect of emotion is also embodied, manifested in the body as distinct topographical maps.

The embodied nature of emotions, their close connection to the body, and the universality of this situation have also led to interesting research. Another research study [22] have examined ancient Neo-Assyrian texts from 934–612 BCE. They analyzed the relationship between emotion and bodily sensation expressions in these texts and mapped the results to body templates. They found that specific body parts were consistently related to different emotion categories in the Akkadian language. Happiness was associated with the liver, heart, and face, while pleasure was associated with the liver. Pride was located in the heart and face, while shame was located in the hands and heart [22]. This study has partly different results compared to the present-day bodily sensation maps. This shows that although the embodied nature of emotions stays the same, how and where different emotions are felt in the body may change over time.

Researchers [23] also investigated how emotions are located in the body through music. They studied the embodiment of music-induced emotions and how music’s emotional aspect influences bodily sensations. Participants listened to happy,

sad, tender, scary, aggressive, and danceable songs and were asked to indicate the bodily regions where they felt changes in activity when listening to music with different emotional contents. Results were recorded on BSMs. Participants marked the chest and head after listening to tender and sad songs, the gut area after scary songs, and the whole body, but particularly the limbs, after listening to happy and danceable songs [23]. Aggressive music was experienced particularly in the head. It was observed that the subjective bodily experience of different emotions induced by music was consistent across individuals and across different cultures.

In fact, mapping different emotional sensations in different locations of the body led to research on how pill shape elicits emotions and how they are felt in the body. Researchers compared angular vs. round-shaped pills and sought to answer the question of whether different pill shapes evoke topographically distinct patterns of felt activity in the body. After showing participants angular and round pills, they asked them to focus on the sensations in their bodies and try to locate their feelings inside their bodies. The study found that angular pills evoked more activation, especially in the head, face, chest, and limbs, while round-shaped pills evoked deactivation throughout the body except for the head [24].

Another study has investigated how bodily sensations of emotions are mapped in schizophrenia (SZ), where bodily self-awareness is disrupted. The inseparability of bodily self-awareness from embodied emotions suggests that topographically distinct emotion-specific body maps would not occur in SZ [25]. In an experiment with people with schizophrenia and control participants, participants were asked to mark 13 emotions on the emBODY tool[18]. While different emotion categories revealed distinct spatial maps in the control group, this was not seen in the SZ group. Additionally, in the SZ group, embodied emotions were less precisely localized and more blurred. In other words, for a given emotion, the SZ group reported both activation and deactivation in the same location [25]. Furthermore, there was less agreement among participants in the SZ group regarding the bodily sensations of emotions. This research demonstrates that distinct spatial patterns of bodily sensations associated with emotions occur and can, moreover, be disrupted in certain disorders such as schizophrenia.

In fact, research shows that differences in BSMs can reveal different personality traits. In their study, Wainio and Armony [26] had participants complete both bodily sensation mapping and several personality trait questionnaires and compared the results. They found that activation in the heart, viscera, and head in BSMs was correlated with antisocial tendencies and impulsivity. They suggested that heart and stomach markings were negatively correlated with antisocial attitudes and impulsivity, and that individuals with antisocial tendencies exhibited reduced physiological responses. It was claimed that the reduced subjective bodily sensations in these individuals also supported the blunted emotional responses observed in psychopathy. Additionally, in participants with high antisocial traits, there was neither a consistent ability to categorize different emotions nor a high degree of similarity within the same emotion.

Similarly, people with bilateral vestibular loss, which affects spatial patterns, were studied to see how their bodily maps of emotions appeared. It was thought that these individuals' disturbed spatial patterns could also affect the mapping of bodily sensations. In the study, although there was no significant difference between BVP patients and controls in bodily sensation maps, the activation for positive emotions such as happiness was less in BVP patients' markings [27].

Besides self-report measures, an fMRI study [28] was conducted in the field. An emotional recall task was performed in fMRI, and the areas activated while participants recalled different emotions were recorded. In addition, in participants who performed motor and tactile stimulation, how different parts of the body responded to these tasks was also recorded. The areas that responded to emotion as well as motor and tactile stimulation were compared, and the areas activated in both tasks were identified, and body maps were created. According to these convergent activities [28], happiness was most commonly located in the hands, while sadness, fear, anger, and serenity were most commonly located in the face. The feet were most commonly activated in sadness, and the trunk was most commonly associated with sadness.

Another study [29] extended the research area from basic emotions to emotions experienced in social scenarios, by using the emBODY tool [18]. Situations such

as bereavement, romantic rejection, birth of a child, and exclusion from a social event were included in the study. The study revealed that both positive and negative social situations lead to activation in the head and chest area, while negative social situations lead to deactivation in the limbs. This study demonstrates that not only basic emotions but also more complex social scenarios can be mapped in the body. Similarly, research on the embodiment of emotions related to more complex phenomena like climate change, war, or the COVID-19 pandemic took the research a step further [30]. Researchers asked participants to locate their feelings when they think of such complex phenomena. Results revealed that participants could differentiate between feelings associated with distinct complex phenomena; they observed activation in the head, chest, abdomen, and hands, besides deactivation in the legs.

Lastly, research extended to map not just emotions but a hundred core subjective feelings, ranging from cognitive and affective mental states (e.g., remembering, concentrating, reasoning, etc.) to somatic sensations [31]. The results showed that various subjective feelings can be grouped into five different categories, and all have their own embodied footprint.

All these reveal that emotions are, like the sense of Self, embodied, and they have a topographical map in which different emotion-related sensations are mapped on different body parts to different extents. Also, this situation depends on contextual factors and is universal. Not only basic emotions, but also complex social emotions and mental states can be mapped onto the body template.

1.3 Current Study

Taken together, the findings regarding the embodiment of the self and emotions led us to the following insight: If the Self and emotions are located in our body template, thoughts may also be located in or in relation to it. However, to our knowledge, there is no such study in the literature that investigated the relationship between thoughts and body template. To research this notion, we

asked two questions: 1) Are our thoughts and images located within our body template? 2) Are different kinds of thoughts and images located at different loci in our body template?

Based on these questions, we designed an experiment that would allow participants to generate different thoughts and images. We provided participants with scenarios in different categories that would enable them to do this. Our study consisted of five categories of scenarios for participants to imagine or think about: visual imagery, auditory imagery, mental arithmetic, abstract thought, and conscious self. We asked participants whether they located these thoughts or images in their body templates, and how/where they localized them.

We proposed two hypotheses: 1) People locate the thoughts and images they have in mind in their body template. 2) Thoughts and images belonging to different categories are located at different loci in the body template.

Chapter 2

Experiment 1

2.1 Methods

2.1.1 Participants

117 healthy participants (77 females) within the age range of 18-58 years ($M = 22.5$, $SD = 8.37$) were recruited for the study. Participants were reimbursed for their time with course credit, a monetary payment, or both. Participants were given a digital copy of the informed consent form before the experiment, and they signed it electronically.

2.1.2 Materials

The experiment was programmed in Python 3.9 using the Pygame library. The task consisted of 11 written scenarios presented in Turkish (see Table 2.1 for the full list of scenarios shown in the experiment). These scenarios were categorized into five different groups: visual imagery, auditory imagery, mental arithmetic, abstract thinking, and conscious-self localization. Specifically, of the 11 scenarios, three were visual imagery scenarios, three were auditory imagery scenarios, two

were mental arithmetic questions, two were abstract thinking questions, and one was on the perceived location of the conscious self in the body. The reason for choosing five different categories of scenarios was to see if there are any differences in the bodily locations of different thought types both within and across categories, and if there are similarities between participants for the same scenario type. Scenarios were presented in a mixed order so that no two items belonging to the same category appeared consecutively. Since we focused on the locations of thoughts and images in the body, and not emotional sensations, scenarios were written in a neutral language, without any emotion-evoking content, to prevent emotions from interfering in the process. We preferred to phrase the scenarios in 1-2 sentences (e.g., “Imagine listening to the birds singing and the sounds of other living creatures in a forest”) instead of giving short descriptions (e.g., “Imagine hearing a birdsong”), so that participants could properly engage in the imagining and thinking process. After the visual imagery scenarios, participants answered a question measuring vividness of visual imagery to see how vividly participants could visualize during imagining.

Table 2.1: *Full list of scenarios (Turkish original and English translation)*

No.	Category	Turkish (Original) Scenario	English Scenario
1	Visual imagery	Bir akşam, Ankara’yı uzaktan ve yukarıdan görebileceğiniz bir lokasyonda, bir bankta oturduğunuzu ve uzaktaki şehrin ışıklarını izlediğinizi hayal edin.	Imagine that you are sitting on a spot where you can see Ankara city far away in the valley below, and watch the city lights from a distance.
2	Auditory imagery	Bir ormanda, kuşların şarkı söylemesini ve ormandaki diğer canlıların seslerini dinlediğinizi hayalinizde canlandırın.	Imagine listening to the birds singing and the sounds of other living creatures in a forest.

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No.	Category	Turkish (Original) Scenario	English Scenario
3	Visual imagery	Bir tabloya (örneğin; bir yağlı boya tablosuna) neredeyse dokunacak kadar yakından bakarak resmin detaylarını incelediğinizi hayalinizde canlandırın.	Imagine looking at a painting, at the details on it very closely, as if you are almost going to touch it.
4	Abstract thought	Lütfen aşağıdaki soruyu okuyun: “Hayatın bir anlamı var mıdır?” Şimdi gözlerinizi kapatın ve bu soruya vereceğiniz cevabı dikkatlice hayalinizde canlandırın.	Please read the question below: Is there a meaning to life? Now, close your eyes and imagine the answer you would give to this question.
5	Mental arithmetic	Lütfen gözlerinizi kapatın ve aşağıda verilen çarpma işlemini yapmaya çalışın: $13 \times 17 = ?$	Please close your eyes and try to perform the following multiplication: $13 \times 17 = ?$
6	Auditory imagery	Söylenenlerin ve seslerin anlaşılmadığı, çok yüksek ve rahatsız edici bir uğultudan ibaret bir gürültü hayal edin. Hemen ardından ortama derin bir sessizliğin hâkim olduğunu hayalinizde canlandırın.	Imagine a noise that is so loud and disturbing that the statements and sounds are incomprehensible. Then, think of a deep silence that dominates the atmosphere right after the noise.
7	Abstract thought	Lütfen aşağıdaki soruyu okuyun: “Başarılı bir hayatın tanımı nedir?” Şimdi gözlerinizi kapatın ve bu soruya vereceğiniz cevabı dikkatlice hayalinizde canlandırın.	Please read the question below: What is the definition of a successful life? Now, close your eyes and imagine the answer you would give to this question.

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No.	Category	Turkish (Original) Scenario	English Scenario
8	Visual imagery	Evinizin içinde dolaşıp etrafı incelediğiniz bir senaryo düşünün. Evin kapısından girip odaları tek tek dolaştığınızı hayal edin.	Imagine a scenario in which you walk around your house and look around. Imagine entering through the door and going through the rooms one by one.
9	Auditory imagery	Bir metro istasyonunda metro beklerken etraftaki sesleri dinlediğinizi düşünün. İstasyona gelmek üzere olan metronun sesini, insanların konuşmalarını ve çevredeki diğer sesleri işittiğinizi hayal edin.	Imagine listening to the sounds around you at a subway station while waiting for the subway. Imagine hearing the sound of the subway that is about to arrive at the station, people talking, and other sounds in the environment.
10	Mental arithmetic	Lütfen gözlerinizi kapatın ve 100'den geriye 7'şerli olarak saymaya çalışın.	Please close your eyes and try to count backwards from 100 by 7s.
11	Conscious self	Elbette vücudunuzun her parçası sizsiniz; fakat sizce “bilinçli siz”in merkezi bedeninizin neresindedir?	Every part of your body is you, for sure; however, when you are mindfully conscious of yourself, where in the body do you find the conscious you is located?

We used four body templates -head drawing front view, head drawing side view, full-body drawing front view, full-body drawing side view- for participants to mark. The two head views appeared together on one screen, and the two full-body views appeared on a separate screen. This arrangement allowed participants to indicate the locations more specifically from two perspectives and enabled us to convert the markings into 3D space. The reason for presenting the head templates besides full-body templates was to pinpoint the exact loci of markings on the head. Participants were instructed to be as specific as possible (e.g., if a

thought was located on the head, they were asked to specify whether it was on the anterior or posterior part of the head, whether it was on the superior part, or whether it was in the more medial part, etc.). The head and full-body templates were presented in random order after each scenario so that participants would not feel obliged to mark the first template presented. See Figure 2.1 for head and full-body templates presented in the study.

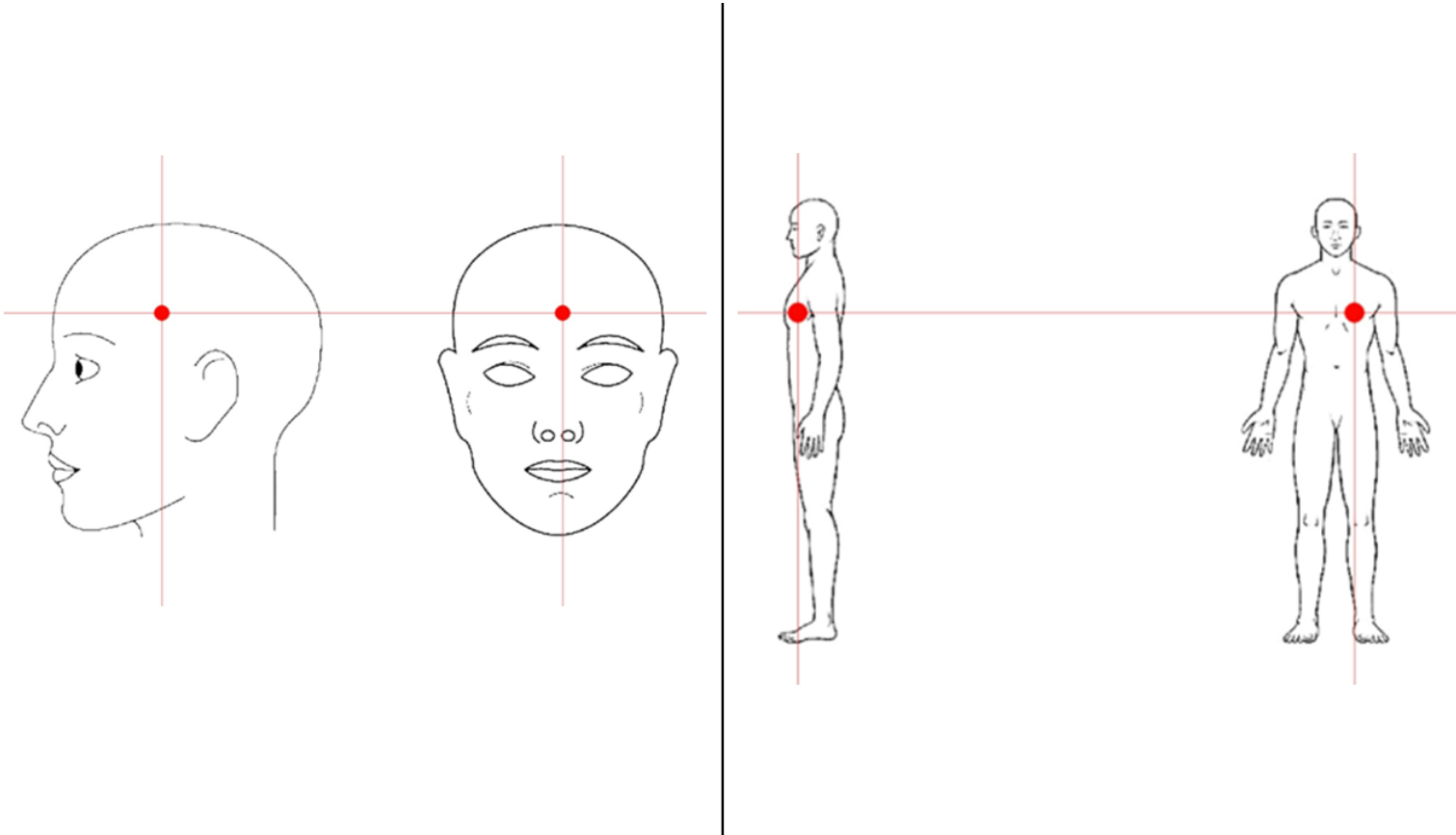


Figure 2.1: Head and Full-body Templates. *The participants marked subjective loci of their thoughts on head and full-body templates. By adjusting the position of the cursor, they could mark both the front view and the side view at the same time.*

2.1.3 Procedure

Participants met the experimenter online (on the Zoom platform). Before starting the experiment, participants received a digital copy of the informed consent form, and they signed it electronically. The experimenter introduced the experiment and sent the experiment link to the participants. Participants downloaded the experiment to their own computers. Throughout the experiment, Zoom remained open, and the participants shared their screens so that the experimenter could monitor the markings they made and the flow of the experiment. At the beginning of the experiment, participants saw a demo screen in which they learned how to mark the body templates accurately by practicing how to position the mouse and make the clicks. Once the demo phase was completed, the experiment began. Participants saw a total of 11 scenarios. After reading every scenario, they were asked to close their eyes and think/imagine the scenario for a while, noting if they located any thoughts and images on their bodies related to the scenario. There was no time limitation; participants were allowed to imagine the scenarios as much as they liked. After the imagination part, they opened their eyes and marked the locations on the body templates. Multiple markings were allowed if they wanted to mark bilateral organs (e.g., eyes, ears) or symmetrical parts on the body (e.g., both sides of the head). A confirmation screen followed each marking, allowing corrections if needed before proceeding. After each visual imagery scenario, participants rated their response from 1-5 regarding vividness of visual imagery (1: No image at all, I only “know” I am thinking of the object; 5: Perfectly realistic, as vivid as real seeing). At the end of the experiment, participants sent the automatically generated data file to the experimenter. See Figure 2.2 for the experimental flow.

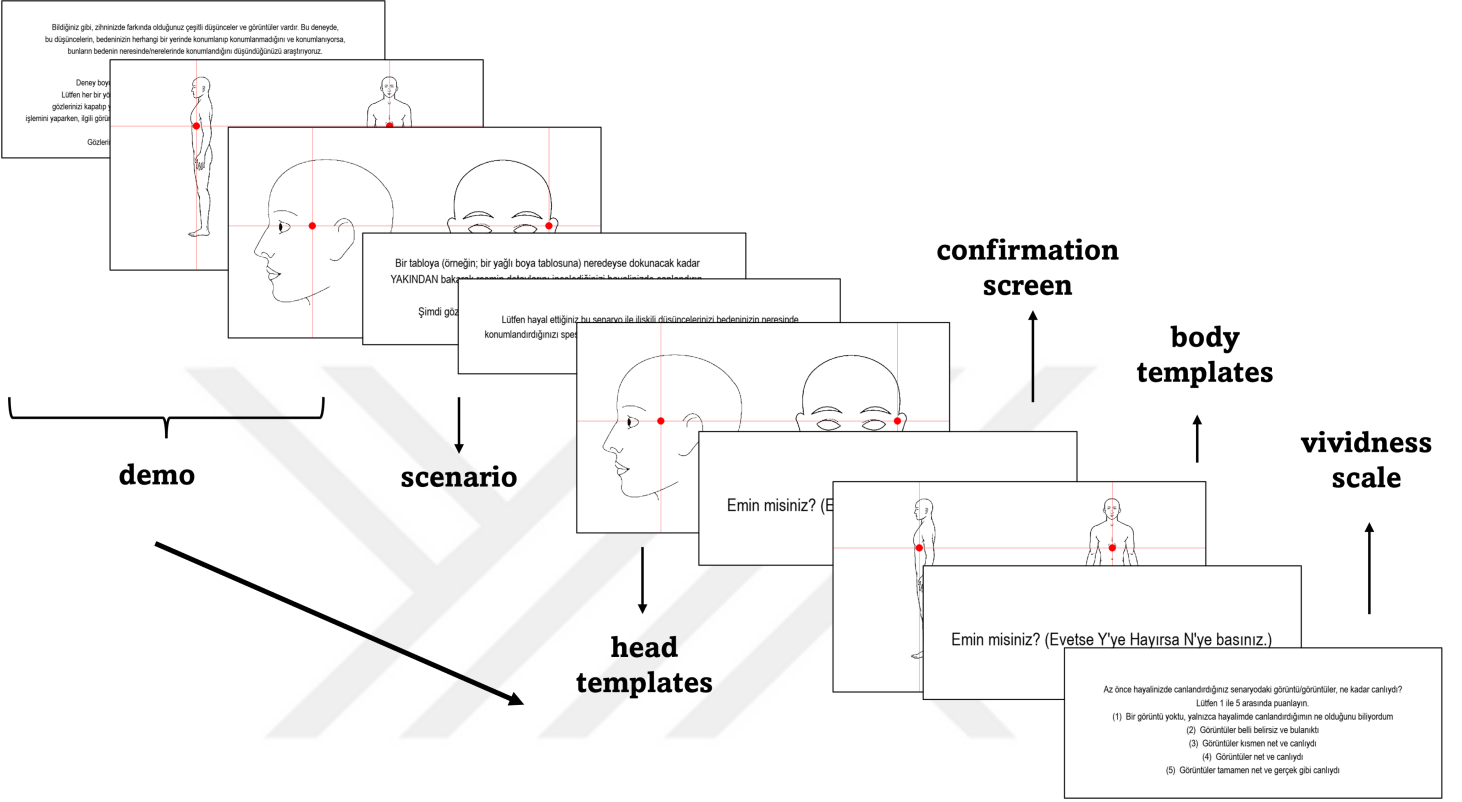


Figure 2.2: *Experimental Flow.* The participants saw a demo screen, followed by eleven scenarios and eleven head-body templates right after every scenario. After every template, they saw a confirmation screen to verify their answers. After visual imagery scenarios, we presented a vividness scale.

2.1.4 Analyses

Qualitative Visual Inspection

We visualized the markings made by participants in the head data using glass-head rendering in MRICroGL to see how the markings were distributed, and examined where different scenarios were located in the 3D transparent head template.

Data Preparation for Spatial Analyses

The x, y, and z coordinates of the points marked by all participants across the 11 scenarios were compiled into a single dataset. These coordinates were standardized using z-scores to normalize the axes for subsequent distance analyses. For each scenario, a centroid was computed by averaging the x, y, and z coordinates of all marked points. These centroids served as the basis for the spatial distance comparisons.

Distance Matrices

To assess the similarity between scenarios, we computed the distances between all scenario centroids using two metrics: 1) Euclidean distance, which measures raw spatial differences between centroids. 2) Mahalanobis distance, which accounts for the internal variance of the scenarios, offering a variance-normalized measure of distance. Using these two distance metrics, we calculated the distances between the centroids of all scenarios and generated the distance matrices. See Appendix A for Euclidean and Mahalanobis distance matrices.

Global Distance Analyses

Using both Euclidean and Mahalanobis distance matrices (11×11), we extracted the upper-triangular values. These were divided into two sets: 1) Within-category distances (8 values - V1-V2, V1-V3, V2-V3, A1-A2, A1-A3, A2-A3, MA1-MA2, AT1-AT2), 2) Between-category distances (47 values - e.g., A1-V1, A1-V2, ... CS-V3). We compared these vectors using a two-tailed Welch's t-test, then converted the t-statistic into a Bayes factor BF_{10} using the Jeffreys-Zellner-Siow prior. The resulting BF_{10} quantifies how much more likely the data are under the hypothesis that within-category distances are smaller than between-category distances (H_1), compared to the null hypothesis of no difference (H_0). This way, we initially examined whether the distances within the same category in our data

were closer than the distances between categories, regardless of category.

Category-Wise Distance Analyses

Next, we evaluated each category individually. For a given category (e.g., visual imagery), we assembled 1) a within-category vector (distances between three visual imagery scenarios, i.e., V1-V2, V1-V3, etc.), 2) a between-category vector (distances between the visual scenarios and all other scenarios, i.e., V1-A1, V1-A2, ..., V2-AT1, V2-AT2, ..., V3-CS). These vectors were compared using a Welch t-test, and the result was converted to BF_{10} . This allowed us to quantify how strongly the data support the hypothesis that within-category distances are smaller, indicating cluster cohesion within each category.

Pair-wise Distance Analyses

To explore specific relationships between category pairs, we tested all possible combinations of the five categories. For a given pair (e.g., visual imagery and auditory imagery), we created 1) a within vector, combining all internal distances within both categories (e.g., V1-V2, V1-V3, V2-V3, A1-A2, A1-A3, A2-A3), 2) a between vector, containing all cross-category distances between the two (e.g., V1-A1, V1-A2, ..., V3-A3). These were again compared using a Welch's unequal-variance t-test, and the statistic was transformed into BF_{10} . The resulting Bayes factor indicates whether the combined within-category distances are significantly smaller than the between-category distances, suggesting whether the pair of categories forms distinct spatial clusters.

Directional Pair-wise Distance Analyses

In the directional analysis, we focused on whether one category is spatially more cohesive than its relation to the other category with which it is paired. For each category pair (e.g., auditory imagery $\rightarrow$ visual imagery), we asked: Are distances

within auditory imagery significantly smaller than distances between auditory imagery and visual imagery? This one-sided test was conducted using Welch’s unequal-variance t-test and converted to BF_{10} using the Jeffreys–Zellner–Siow prior. Importantly, the direction was reversed (e.g., visual imagery $\rightarrow$ auditory imagery) to yield an independent test. Directional clustering does not assume symmetry.

Heat Map Visualizations

To visualize the relationships among scenarios, we generated 11×11 heat maps from the Euclidean and Mahalanobis distance matrices. In the heat maps, dark blue/navy cells indicate closer distances, and yellow cells indicate greater distances. See Appendix B for 11×11 scenario-based heat maps.

Additionally, we visualized pairwise BF_{10} results (for both Euclidean and Mahalanobis distances) by converting them to $\log_{10}BF$ values. This transformation made the heat maps more interpretable, red indicates strong evidence for clustering (support for H_1), and white indicates neutrality (data equally likely under H_1 and H_0). We also visualized directional BF_{10} results as $\log_{10}BF$ heat maps for both distance types, highlighting asymmetrical clustering patterns across category pairs.

Only head data were analyzed in the scope of this thesis study; full-body data analyses were not included in the thesis.

2.2 Results

2.2.1 Qualitative Visual Inspection

Visual inspection of the glass-head renderings revealed clear differences in spatial clustering when auditory imagery and visual imagery markings were compared. Auditory imagery points were concentrated in the posterior portion of the head

and extended laterally around the ears, whereas visual imagery points were concentrated anteriorly, with a marked focus over the eye region (see Figure 2.3). A comparable divergence emerged between auditory imagery and mental arithmetic: mental arithmetic points clustered anteriorly and over the eye area, while auditory imagery points occupied the lateral-posterior portion of the head (see Figure 2.4).

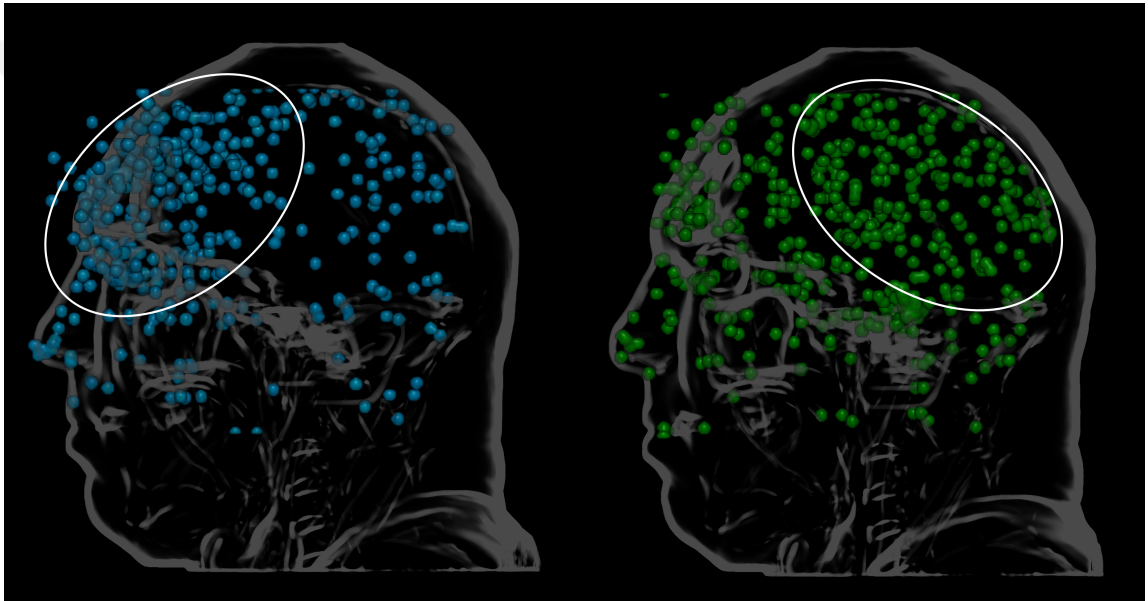


Figure 2.3: *Glass-head visualizations.* *Visual imagery (on the left) and auditory imagery (on the right) markings. The areas where the two scenarios differ in intensity are marked with ellipses.*

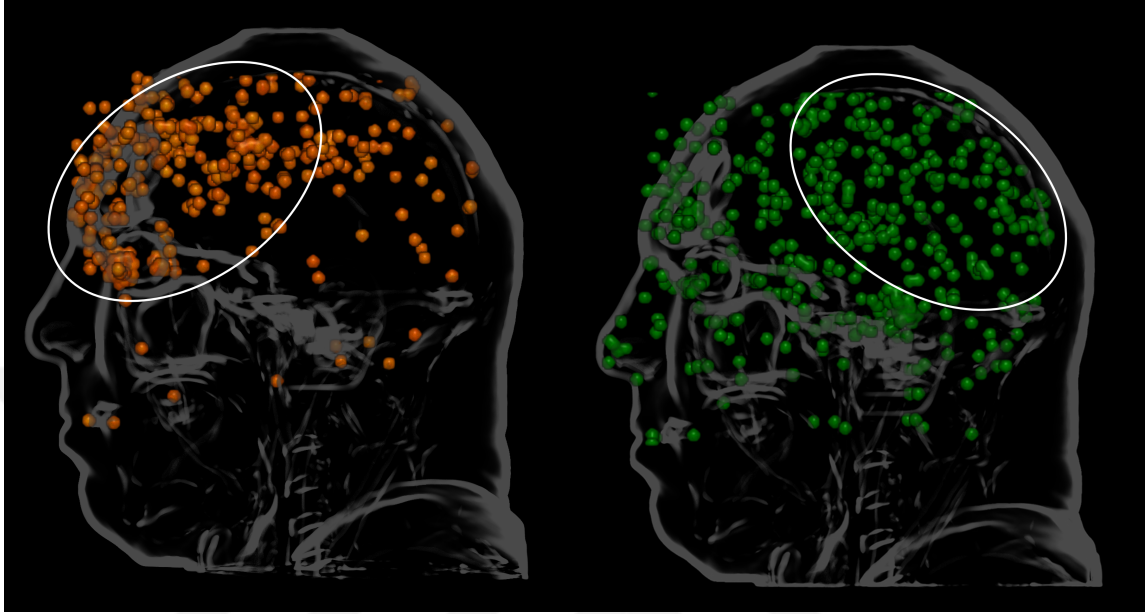


Figure 2.4: *Glass-head visualizations.* *Mental arithmetic (on the left) and auditory imagery (on the right) markings. The areas where the two scenarios differ in intensity are marked with ellipses.*

2.2.2 Distance Matrices

Euclidean Distances When Euclidean distances were calculated between the centroids of all 11 scenarios, the two mental arithmetic scenarios were the closest ($d = 0.106$), whereas the greatest separation was observed between a mental arithmetic scenario and an auditory imagery scenario ($d = 0.859$).

Mahalanobis Distances In Mahalanobis distances, the two mental arithmetic scenarios were again the closest ($d = 0.609$), whereas the greatest separation occurred between a visual imagery scenario and an auditory imagery scenario ($d = 3.850$).

11x11 Euclidean and Mahalanobis distance matrices for all scenarios are presented in Appendix B.

2.2.3 Global Distance Analyses

Euclidean Distances Global within-category distances ($M = 0.27$, $SD = 0.13$) were smaller than global between-category distances ($M = 0.49$, $SD = 0.20$), Welch's $t(13.10) = -4.16$, $p = .001$, $BF_{10} = 167$, indicating decisive evidence for the predicted difference.

Mahalanobis Distances Global within-category distances ($M = 1.89$, $SD = 0.81$) were smaller than global between-category distances ($M = 2.40$, $SD = 0.76$), Welch's $t(9.24) = -1.65$, $p = .131$, $BF_{10} = 0.98$, indicating little to no evidence for a difference once between-category dispersion was taken into account.

See Table 2.2 for descriptive and inferential statistics.

Table 2.2: *Global Distance Statistics by Euclidean and Mahalanobis Distances*

Distance	Within		Between		t	df	p	BF_{10}
	M	SD	M	SD				
euclid	0.27	0.13	0.49	0.20	-4.16	13.10	.001	167.03
mahalanobis	1.89	0.81	2.40	0.76	-1.65	9.24	.131	0.98

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favor of H_1 over H_0 . Exact p values are reported unless $p < .001$.

2.2.4 Category-wise Distance Analyses

Euclidean Distances Three of the five categories showed significantly smaller within-category distances than between-category distances.

Mental arithmetic yielded the largest within-category similarity, $t(28,509) = -25.28$, $p < .001$, $BF_{10} = 2.63 \times 10^{136}$. Conscious self showed a strong effect, Welch's $t(3,578) = -9.00$, $p < .001$, $BF_{10} = 7.46 \times 10^{15}$. Auditory imagery

also exhibited robust within-category similarity relative to between-category distances, Welch's $t(50,305) = -5.62$, $p < .001$, $BF_{10} = 4.73 \times 10^4$. Abstract thought showed a modest but significant reversal of the expected pattern—higher within- than between-category distances—whereas visual imagery distances did not differ between within- and between-category conditions.

Mahalanobis Distances The Mahalanobis analysis yielded a highly similar pattern with Euclidean distances.

Auditory imagery demonstrated substantial within-category similarity, Welch's $t(50,748) = -10.67$, $p < .001$, $BF_{10} = 3.21 \times 10^{22}$. Conscious self also showed a robust effect, Welch's $t(3,563) = -8.54$, $p < .001$, $BF_{10} = 1.33 \times 10^{14}$. Mental arithmetic exhibited the strongest within-category similarity, $t(28,097) = -25.29$, $p < .001$, $BF_{10} = 3.30 \times 10^{136}$. By contrast, abstract thought showed lower within-category distances, $t(14,558) = 4.58$, $p < .001$, $BF_{10} = 3.84 \times 10^2$. Finally, visual imagery remained non-significant, Welch's $t(47,151) = -0.48$, $p = .629$, $BF_{10} = 0.01$.

See Tables 2.3 and 2.4 for descriptive and inferential statistics.

Table 2.3: *Category-wise Distance Statistics (**Euclidean**)*

Category	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought	2.17	1.04	2.14	0.99	2.80	14,616.43	= .005	0.54
Auditory Imagery	2.16	0.98	2.19	0.97	-5.62	50,305.01	< .001	4.73×10^4
Conscious Self	1.89	0.87	2.03	0.93	-9.00	3,578.15	< .001	7.46×10^{15}
Mental Arithmetic	1.90	0.85	2.06	0.94	-25.28	28,508.67	< .001	2.63×10^{136}
Visual Imagery	2.15	1.02	2.14	0.98	1.29	47,144.52	= .195	0.01

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favor of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 2.4: *Category-wise Distance Statistics (Mahalanobis)*

Category	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought	2.33	1.06	2.28	1.00	4.58	14,558.26	$< .001$	3.84×10^2
Auditory Imagery	2.26	0.95	2.32	0.95	-10.67	50,748.03	$< .001$	3.21×10^{22}
Conscious Self	2.02	0.90	2.16	0.94	-8.54	3,562.61	$< .001$	1.33×10^{14}
Mental Arithmetic	2.04	0.87	2.20	0.95	-25.29	28,097.31	$< .001$	3.30×10^{136}
Visual Imagery	2.27	1.02	2.27	0.97	-0.48	47,150.60	$= .629$	0.01

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favor of H_1 over H_0 . Exact p values are reported unless $p < .001$.

2.2.5 Pair-wise Distance Analyses

Euclidean Distances Of ten category pairs, four showed strong evidence of forming distinct within-category clusters when paired together with another category. The strongest effects were found for the auditory–imagery and visual–imagery pair, Welch’s $t(141,639) = -15.23$, $p < .001$, $\text{BF}_{10} = 1.30 \times 10^{48}$, and for the auditory–imagery and mental–arithmetic pair, $t(112,468) = -14.54$, $p < .001$, $\text{BF}_{10} = 5.00 \times 10^{43}$. The abstract–thought and mental–arithmetic pair showed a substantial effect, Welch’s $t(65,862) = -6.93$, $p < .001$, $\text{BF}_{10} = 2.34 \times 10^8$. Likewise, the abstract–thought and auditory–imagery pair produced a robust effect, $t(89,441) = -7.16$, $p < .001$, $\text{BF}_{10} = 1.04 \times 10^9$.

Mahalanobis Distances The Mahalanobis analysis yielded a highly similar pattern: out of ten category pairs, five showed robust evidence of forming within-category clusters when analysed together. The largest effect was observed for the auditory–imagery and mental–arithmetic pair, Welch’s $t(112,498) = -18.72$, $p < .001$, $\text{BF}_{10} = 5.9 \times 10^{73}$, followed closely by the auditory–imagery and visual–imagery pair, $t(141,639) = -18.58$, $p < .001$, $\text{BF}_{10} = 4.8 \times 10^{72}$. The abstract–thought and auditory–imagery pair also showed a substantial effect, $t(89,317.00) = -9.899124$, $p < .001$, $\text{BF}_{10} = 1.377 \times 10^{19}$. Likewise, the abstract–thought and mental–arithmetic pair produced a robust effect, $t(65,879.00) = -7.911494$, $p < .001$, $\text{BF}_{10} = 3.355 \times 10^{11}$. Finally, abstract thought and visual imagery revealed a strong effect, $t(87,819.00) = -4.413786$, $p < .001$, $\text{BF}_{10} = 1.28591 \times 10^2$.

See Tables 2.5 and 2.6 for descriptive and inferential statistics.

Table 2.5: *Pair-wise Distance Statistics (**Euclidean**)*

Category Pair	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought - Auditory Imagery	2.16	0.99	2.21	0.99	-7.16	89,441.49	< .001	1.04×10^9
Abstract Thought - Conscious Self	2.11	1.02	2.03	0.97	6.31	27,776.33	< .001	5.83×10^6
Abstract Thought - Mental Arithmetic	2.00	0.93	2.05	0.96	-6.93	65,862.41	< .001	2.34×10^8
Abstract Thought - Visual Imagery	2.15	1.03	2.17	1.00	-2.58	87,920.66	= .010	0.212
Auditory Imagery - Conscious Self	2.13	0.97	2.11	0.94	2.77	45,996.75	= .006	0.440
Auditory Imagery - Mental Arithmetic	2.06	0.94	2.14	0.97	-14.54	112,467.60	< .001	5.01×10^{43}
Auditory Imagery - Visual Imagery	2.15	1.00	2.23	0.99	-15.23	141,639.00	< .001	1.34×10^{48}
Conscious Self - Mental Arithmetic	1.90	0.85	1.89	0.85	1.08	35,718.80	= .282	0.020
Conscious Self - Visual Imagery	2.13	1.01	2.04	0.95	10.33	46,770.02	< .001	1.35×10^{21}
Mental Arithmetic - Visual Imagery	2.06	0.96	2.04	0.95	2.88	110,202.81	= .004	0.432

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favor of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 2.6: *Pair-wise Distance Statistics (Mahalanobis)*

Category Pair	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought - Auditory Imagery	2.28	0.98	2.34	0.98	-9.90	89,317.32	< .001	1.38×10^{19}
Abstract Thought - Conscious Self	2.26	1.04	2.18	0.99	6.95	27,779.38	< .001	3.88×10^8
Abstract Thought - Mental Arithmetic	2.14	0.96	2.20	0.98	-7.91	65,878.55	< .001	3.35×10^{11}
Abstract Thought - Visual Imagery	2.29	1.03	2.32	1.02	-4.41	87,819.16	< .001	1.29×10^2
Auditory Imagery - Conscious Self	2.24	0.94	2.23	0.93	1.27	45,676.14	= .204	0.02
Auditory Imagery - Mental Arithmetic	2.18	0.93	2.28	0.92	-18.72	112,497.85	< .001	5.95×10^{73}
Auditory Imagery - Visual Imagery	2.27	0.98	2.36	0.96	-18.58	141,638.68	< .001	4.77×10^{72}
Conscious Self - Mental Arithmetic	2.03	0.88	2.03	0.88	0.52	35,730.91	= .604	0.01
Conscious Self - Visual Imagery	2.25	1.01	2.17	0.95	9.50	46,504.82	< .001	3.56×10^{17}
Mental Arithmetic - Visual Imagery	2.18	0.97	2.17	0.96	2.69	110,198.50	= .007	0.25

2.2.6 Directional Pair-wise Distance Analyses

Euclidean Distances Of the twenty directional pair-wise comparisons, ten showed significant within-category clustering. The strongest effect occurred for the mental-arithmetic when paired with auditory-imagery, Welch's $t(42,007) = -33.93$, $p < .001$, $BF_{10} = 1.215 \times 10^{246}$. The next-largest effects again involved mental arithmetic when paired with visual imagery and then with abstract thought. Conscious self also demonstrated a robust clustering effect when paired with auditory imagery, Welch's $t(4,450) = -13.58$, $p < .001$, $BF_{10} = 1.438 \times 10^{38}$.

Mahalanobis Distances The Mahalanobis analysis closely mirrored the Euclidean pattern, adding further evidence for within-category clustering: eleven of the twenty directional comparisons were significant. The largest effect again occurred for the mental-arithmetic when paired with auditory-imagery, Welch's $t(40,026) = -34.12$, $p < .001$, $BF_{10} = 7.306 \times 10^{248}$. Mental arithmetic also yielded very strong effects when paired with abstract thought and with visual imagery. In addition, visual imagery—nonsignificant in the Euclidean analysis—showed a strong effect when paired with abstract thought, Welch's $t(73,867) = -6.20$, $p < .001$, $BF_{10} = 1.80 \times 10^6$.

See Tables 2.7-2.10 for descriptive and inferential statistics.

Table 2.7: *Directional Pair-wise Statistics for Abstract Thought, Auditory Imagery and Conscious Self Scenarios (Euclidean)*

Direction	BF_{10}	t	df	p	M_{within}	SD_{within}	$M_{between}$	$SD_{between}$
abstract thought $\rightarrow$ auditory imagery	10.77	-3.70	19 433	< .001	2.17	1.04	2.21	0.99
abstract thought $\rightarrow$ conscious self	7.18×10^{21}	10.46	24 932	< .001	2.17	1.04	2.03	0.97
abstract thought $\rightarrow$ mental arithmetic	2.59×10^{22}	10.60	20 821	< .001	2.17	1.04	2.05	0.96
abstract thought $\rightarrow$ visual imagery	0.01	-0.47	19 766	.635	2.17	1.04	2.17	1.00
auditory imagery $\rightarrow$ abstract thought	8.13×10^8	-7.12	76 850	< .001	2.16	0.98	2.21	0.99
auditory imagery $\rightarrow$ conscious self	2.43×10^4	5.43	47 093	< .001	2.16	0.98	2.11	0.94
auditory imagery $\rightarrow$ mental arithmetic	0.03	1.73	74 768	.083	2.16	0.98	2.14	0.94
auditory imagery $\rightarrow$ visual imagery	1.36×10^{30}	-12.20	72 437	< .001	2.16	0.98	2.23	0.98
conscious self $\rightarrow$ abstract thought	6.74×10^{13}	-8.46	5 448	< .001	1.89	0.87	2.03	0.97
conscious self $\rightarrow$ auditory imagery	1.44×10^{38}	-13.58	4 450	< .001	1.89	0.87	2.11	0.94
conscious self $\rightarrow$ mental arithmetic	0.02	-0.46	4 527	.645	1.89	0.87	1.89	0.85
conscious self $\rightarrow$ visual imagery	2.11×10^{17}	-9.37	4 480	< .001	1.89	0.87	2.04	0.95

Note. BF_{10} = Bayes factor comparing the alternative to the null. M = mean; SD = standard deviation. Two-tailed p values < .001 are reported as “< .001”.

Table 2.8: *Directional Pair-wise Statistics for Mental Arithmetic and Visual Imagery Scenarios (**Euclidean**)*

Direction	BF_{10}	t	df	p	M_{within}	SD_{within}	$M_{between}$	$SD_{between}$
mental arithmetic $\rightarrow$ abstract thought	1.86×10^{74}	-18.77	48 866	$< .001$	1.90	0.85	2.05	0.96
mental arithmetic $\rightarrow$ auditory imagery	1.22×10^{246}	-33.93	42 007	$< .001$	1.90	0.85	2.14	0.94
mental arithmetic $\rightarrow$ conscious self	0.03	1.34	35 647	.180	1.90	0.85	1.89	0.85
mental arithmetic $\rightarrow$ visual imagery	6.40×10^{76}	-19.08	42 851	$< .001$	1.90	0.85	2.04	0.95
visual imagery $\rightarrow$ abstract thought	0.74	-3.00	73 532	.003	2.15	1.02	2.17	1.00
visual imagery $\rightarrow$ auditory imagery	1.58×10^{32}	-12.58	66 230	$< .001$	2.15	1.02	2.23	0.98
visual imagery $\rightarrow$ conscious self	2.11×10^{33}	12.77	47 806	$< .001$	2.15	1.02	2.04	0.95
visual imagery $\rightarrow$ mental arithmetic	2.31×10^{53}	16.00	70 035	$< .001$	2.15	1.02	2.04	0.95

Note. BF_{10} = Bayes factor comparing the alternative to the null. M = mean; SD = standard deviation. Two-tailed p values $< .001$ are reported as “ $< .001$ ”.

Table 2.9: *Directional Pair-wise Statistics for Abstract Thought, Auditory Imagery and Conscious Self Scenarios (**Ma-**
halanobis)*

Direction	BF_{10}	t	df	p	M_{within}	SD_{within}	$M_{between}$	$SD_{between}$
abstract thought $\rightarrow$ auditory imagery	0.03	-1.29	18 979	.197	2.33	1.06	2.34	0.98
abstract thought $\rightarrow$ conscious self	2.08×10^{26}	11.41	24 941	< .001	2.33	1.06	2.18	0.99
abstract thought $\rightarrow$ mental arithmetic	9.58×10^{25}	11.35	20 923	< .001	2.33	1.06	2.20	0.98
abstract thought $\rightarrow$ visual imagery	0.02	1.20	19 598	.231	2.33	1.06	2.32	1.02
auditory imagery $\rightarrow$ abstract thought	3.61×10^{28}	-11.89	77 296	< .001	2.26	0.95	2.34	0.98
auditory imagery $\rightarrow$ conscious self	10.13	3.73	46 652	< .001	2.26	0.95	2.23	0.93
auditory imagery $\rightarrow$ mental arithmetic	1.09	-3.15	75 582	.002	2.26	0.95	2.28	0.92
auditory imagery $\rightarrow$ visual imagery	5.37×10^{55}	-16.34	73 108	< .001	2.26	0.95	2.36	0.96
conscious self $\rightarrow$ abstract thought	4.01×10^{15}	-8.93	5 418	< .001	2.02	0.90	2.18	0.99
conscious self $\rightarrow$ auditory imagery	5.98×10^{31}	-12.44	4 330	< .001	2.02	0.90	2.23	0.93
conscious self $\rightarrow$ mental arithmetic	0.03	-0.55	4 535	.586	2.02	0.90	2.03	0.88
conscious self $\rightarrow$ visual imagery	1.07×10^{15}	-8.78	4 422	< .001	2.02	0.90	2.17	0.95

Note. BF_{10} = Bayes factor comparing the alternative to the null. M = mean; SD = standard deviation. Two-tailed p values < .001 are reported as “< .001”.

Table 2.10: *Directional Pair-wise Statistics for Mental Arithmetic and Visual Imagery Scenarios (**Mahalanobis**)*

Direction	BF_{10}	t	df	p	M_{within}	SD_{within}	$M_{between}$	$SD_{between}$
mental arithmetic $\rightarrow$ abstract thought	8.46×10^{90}	-20.73	48 686	$< .001$	2.04	0.87	2.20	0.98
mental arithmetic $\rightarrow$ auditory imagery	7.31×10^{248}	-34.12	40 026	$< .001$	2.04	0.87	2.28	0.92
mental arithmetic $\rightarrow$ conscious self	0.01	0.74	35 665	.460	2.04	0.87	2.03	0.88
mental arithmetic $\rightarrow$ visual imagery	1.01×10^{67}	-17.85	41 878	$< .001$	2.04	0.87	2.17	0.96
visual imagery $\rightarrow$ abstract thought	1.8×10^6	-6.20	73 867	$< .001$	2.27	1.02	2.32	1.02
visual imagery $\rightarrow$ auditory imagery	5.8×10^{39}	-13.90	65 112	$< .001$	2.27	1.02	2.36	0.96
visual imagery $\rightarrow$ conscious self	1.82×10^{28}	11.82	47 506	$< .001$	2.27	1.02	2.17	0.95
visual imagery $\rightarrow$ mental arithmetic	2.18×10^{48}	15.25	70 678	$< .001$	2.27	1.02	2.17	0.96

Note. BF_{10} = Bayes factor comparing the alternative to the null. M = mean; SD = standard deviation. Two-tailed p values $< .001$ are reported as “ $< .001$ ”.

2.2.7 Heat Maps

When the pair-wise Euclidean-distance results were visualized, the most clearly defined within-category cluster emerged between visual imagery and auditory imagery. In addition, the mental arithmetic–auditory imagery pairing formed clusters that were widely separated from one another, and—similarly—the visual imagery–conscious self pairing produced distinct clusters. See Figure 2.5 for details.

Visualization of the pair-wise Mahalanobis distance revealed a pattern largely parallel to the Euclidean results. The visual imagery–auditory imagery cluster remained prominent, whereas the clustering of mental arithmetic with auditory imagery grew more pronounced. Clustering between auditory imagery and abstract thought also intensified. See Figure 2.6 for details.

When the directional pair-wise Euclidean-distance matrix was visualized, mental arithmetic formed the most distinct cluster when paired with auditory imagery. The next-strongest mental arithmetic clusters were observed with abstract thought and, subsequently, with visual imagery. Complementing this pattern, visual imagery also yielded clear clusters when combined with mental arithmetic, conscious self, and auditory imagery. See Figure 2.7 for details.

Visualization of the directional pair-wise Mahalanobis-distance results replicated the overall pattern observed with Euclidean distances. Mental arithmetic exhibited the most distinct clustering, particularly in its pairings with auditory imagery, abstract thought, and visual imagery. In turn, visual imagery showed the clearest clusters when paired with auditory imagery, mental arithmetic, and conscious self. See Figure 2.8 for details.

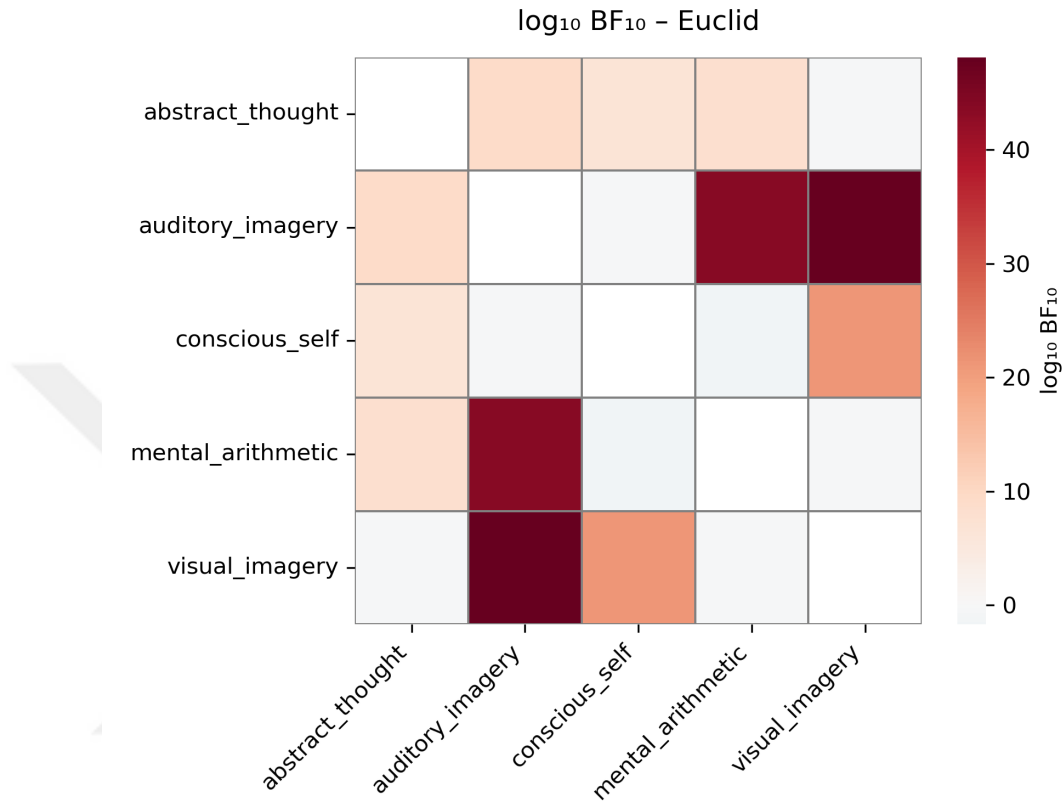


Figure 2.5: $\log_{10}BF_{10}$ *pair-wise heat map* – *Euclidean*. Dark color indicates stronger evidence for clustering - when two categories are combined, each category makes more robust clusters within itself. $\log_{10}BF_{10}$ values are used for better visualization.

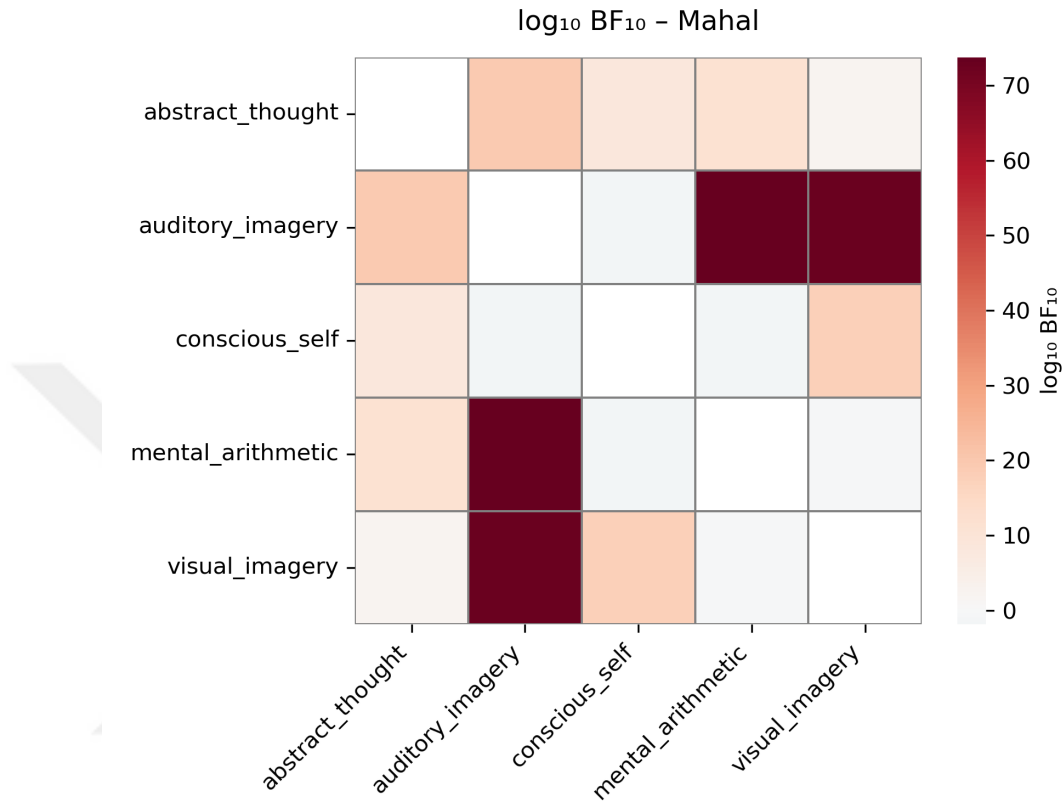


Figure 2.6: $\log_{10}BF_{10}$ *pair-wise heat map* – *Mahalanobis*. Dark color indicates stronger evidence for clustering - when two categories are combined, each category makes more robust clusters within itself. $\log_{10}BF_{10}$ values are used for better visualization.

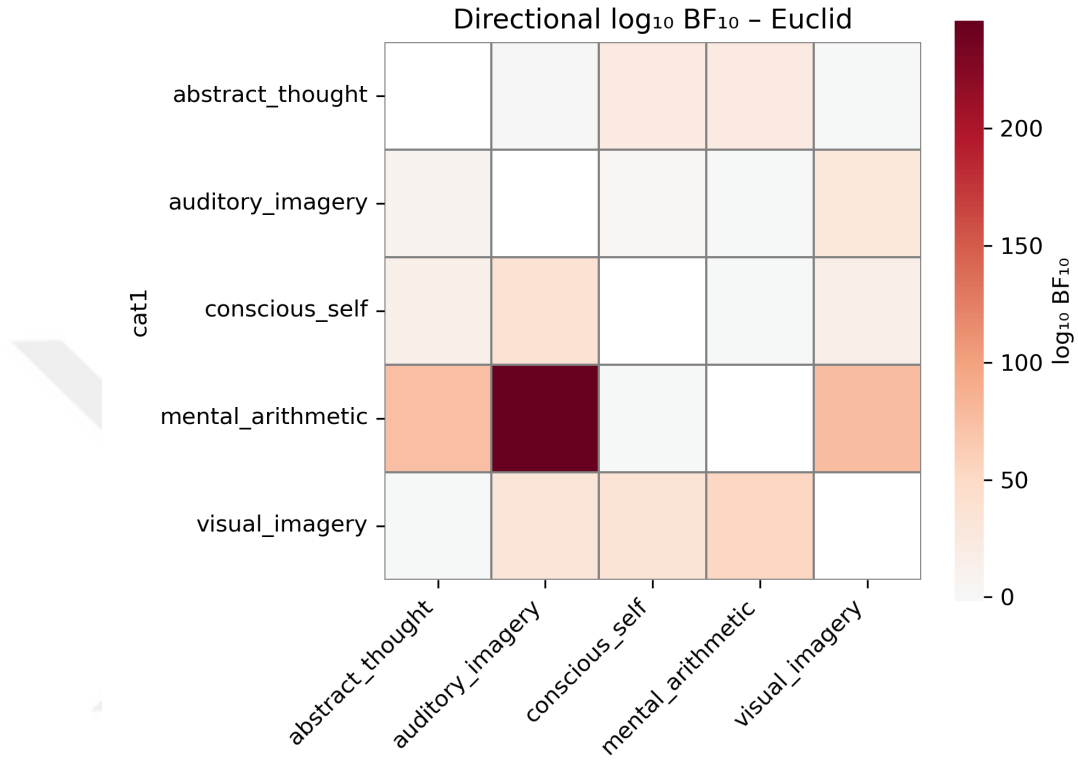


Figure 2.7: $\log_{10} BF_{10}$ *directional pair-wise heat map – Euclidean*. Dark color indicates stronger evidence for the category on the y axis, making more robust clusters within itself compared to the category it is paired with on the x axis. $\log_{10} BF_{10}$ values are used for better visualization.

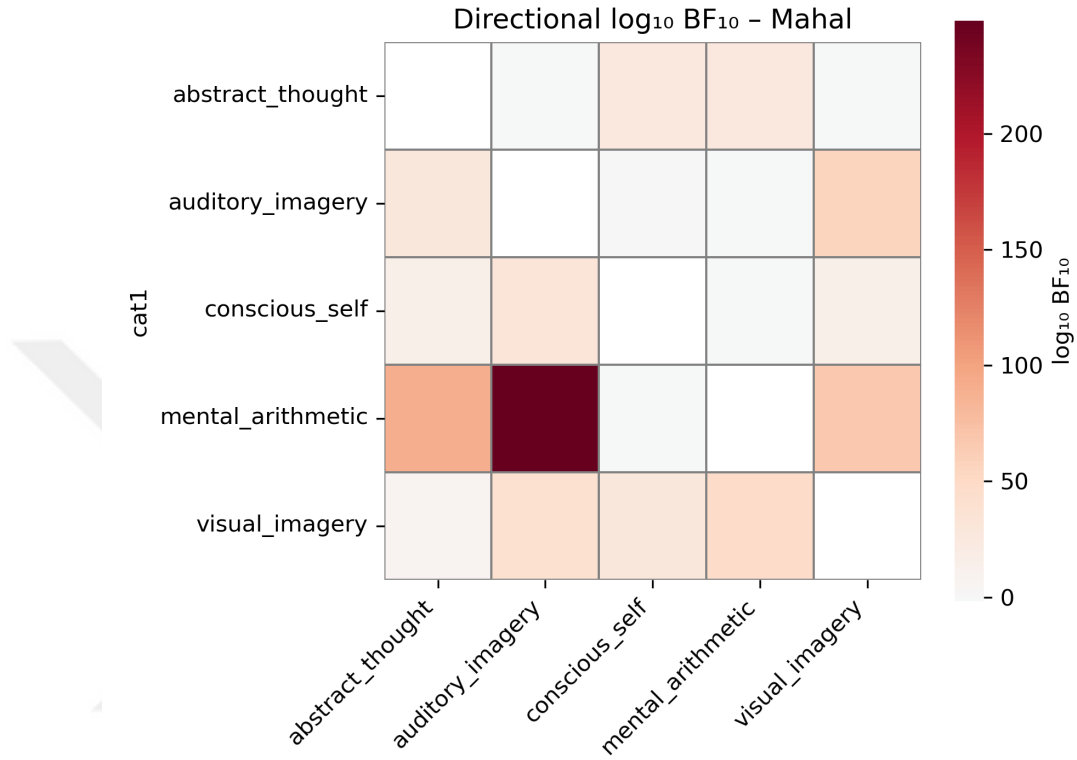


Figure 2.8: $\log_{10}BF_{10}$ *directional pair-wise heat map – Mahalanobis*. Dark color indicates stronger evidence for the category on the y axis, making more robust clusters within itself compared to the category it is paired with on the x axis. $\log_{10}BF_{10}$ values are used for better visualization.

Scenario-based Euclidean and Mahalanobis heat maps are presented in Appendix B.

2.3 Discussion

Global distance analyses using Euclidean distance revealed a clear category structure: the average distance among scenarios within the same category

was clearly smaller than the average distance between scenarios from different categories. However, this pattern disappeared when Mahalanobis distances were applied. Once the internal covariance of each scenario was taken into account, the within-category dispersion became so heterogeneous that the mean within-category distance was no longer reliably smaller than the mean between-category distance. Taken together, these findings suggest that, scenarios do cluster by category, but extensive variability within several categories weakens the significance of this clustering once the in-category variances are considered.

Category-wise analyses revealed that mental arithmetic formed the closest and most distinctive cluster, located in the top-front center of the head. Conscious self, although less compact, was also well-defined, located toward the front center of the head. Auditory imagery exhibited a coherent cluster in the mid-posterior region. In contrast, visual imagery and abstract thought were widely scattered, showing no consistent localization relative to the other categories. Internal variance amplified the distinctiveness of mental arithmetic and auditory imagery: their within-category distances remained small, whereas the other categories appeared both distant and dispersed. Conscious self still separated from the rest, but its effect size decreased because of moderate internal variance. Visual imagery became more compact, while abstract thought displayed such a large in-category variance that its Mahalanobis distance exceeded the global average.

When we compared the categories pair by pair, we saw clear differences. Visual imagery and auditory imagery stayed tightly grouped within themselves and far from each other, making them easy to separate. The same strong gap appeared between auditory imagery and mental arithmetic, and also between auditory imagery and abstract thought. Abstract thought and mental arithmetic were still distinct, but their gap was a bit smaller than in the other pairs. By contrast, conscious self and visual imagery ended up close together, so it was hard to distinguish them.

Directional pair-wise analyses confirmed that some categories naturally gather together more tightly than others. Mental arithmetic always formed its own compact cluster: whether we paired it with visual imagery or abstract thought,

it stayed neat and separate, which is why the gap between mental arithmetic and the other tasks was so clear. Conscious self also grouped closely within itself; when matched with categories other than mental arithmetic, it remained tidy and stood out from auditory imagery, visual imagery, and abstract thought, though its separation from the rest was less decisive. Abstract thought looked very distinct when put together with auditory imagery, yet it behaved like the other categories in most other pairings. Visual imagery showed a tight clustering that was very different from auditory imagery, but was otherwise integrated with other tasks and did not draw a sharp boundary.

In short, our results suggest that people do have an intuitive bodily map of certain kinds of thinking, and in this map, mental arithmetic and auditory imagery showed the most evident and distinct pattern.

Chapter 3

Experiment 2

Vision and hearing affect how we perceive and interpret external stimuli, thoughts, and emotions. In a second experiment, we replicated the first part with blind and deaf individuals to see how the vision and hearing loss would affect behavior in this study. We believed that there might be differences in the way blind and deaf individuals locate their thoughts in the body, particularly in visual and auditory imagery scenarios.

3.1 Methods

3.1.1 Participants

17 blind participants (6 females) within the age range of 18-57 ($M = 35.4$, $SD = 10.7$), and 15 deaf participants (5 females) within the age range of 23-60 ($M = 38.1$, $SD = 11.4$) were recruited for the study. Of the seventeen blind participants, eleven were congenitally blind, five were early-blind, and one was late-blind. All fifteen deaf participants were congenitally deaf. Participants were reimbursed for their time with a monetary payment. All participants' consent was taken before the experiment.

3.1.2 Materials

The materials for Experiment 2 were identical to those used in Experiment 1. The same scenarios and body templates used in Experiment 1 were also used in Experiment 2. See Section 2.1.2 for details of the materials.

3.1.3 Procedure

The procedure for Experiment 2 was identical to Experiment 1 except for a few adjustments. For blind participants, the experimenter read the scenarios aloud. Participants described the perceived location of thoughts to the experimenter and pointed to the corresponding area on their own bodies, and the experimenter marked the templates accordingly. For deaf participants, a sign-language interpreter translated the scenarios into sign language. Other than these modifications, the same experimental procedure was followed as in Experiment 1. See Section 2.1.3 for details of the procedure.

3.1.4 Analyses

The analyses for Experiment 2 were identical to Experiment 1. See Section 2.1.4 for details of the analysis pipeline.

3.2 Results

3.2.1 Blind Analyses

Qualitative Visual Inspection

Visual inspection of the glass-head renderings revealed differences in spatial clustering when auditory imagery and visual imagery markings were compared. Auditory imagery points were concentrated in the posterior-ventral portion of the head and extended laterally around the ears, whereas visual imagery points were concentrated anteriorly, with a marked focus over the eye region (see Figure 3.1). A comparable divergence emerged between auditory imagery and abstract thought: abstract thought points clustered dorsally, while auditory imagery points occupied the ventral portion of the head, clustered around the ears (see Figure 3.2).

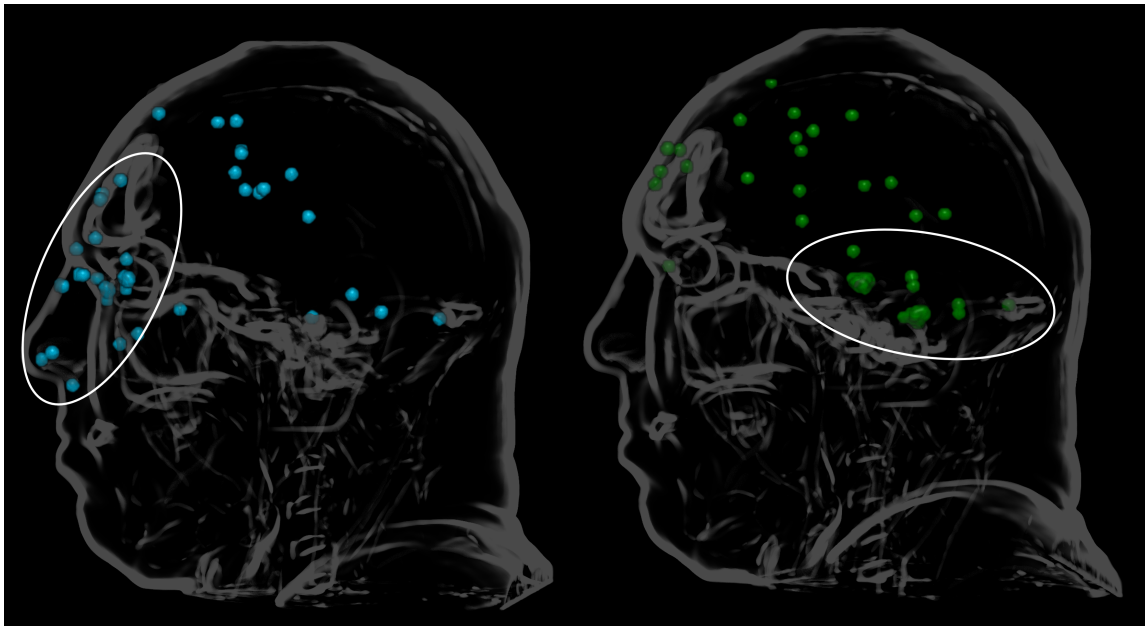


Figure 3.1: *Glass-head visualizations in blind.* Visual imagery (on the left) and auditory imagery (on the right) markings. The areas where the two scenarios differ in intensity are marked with ellipses.

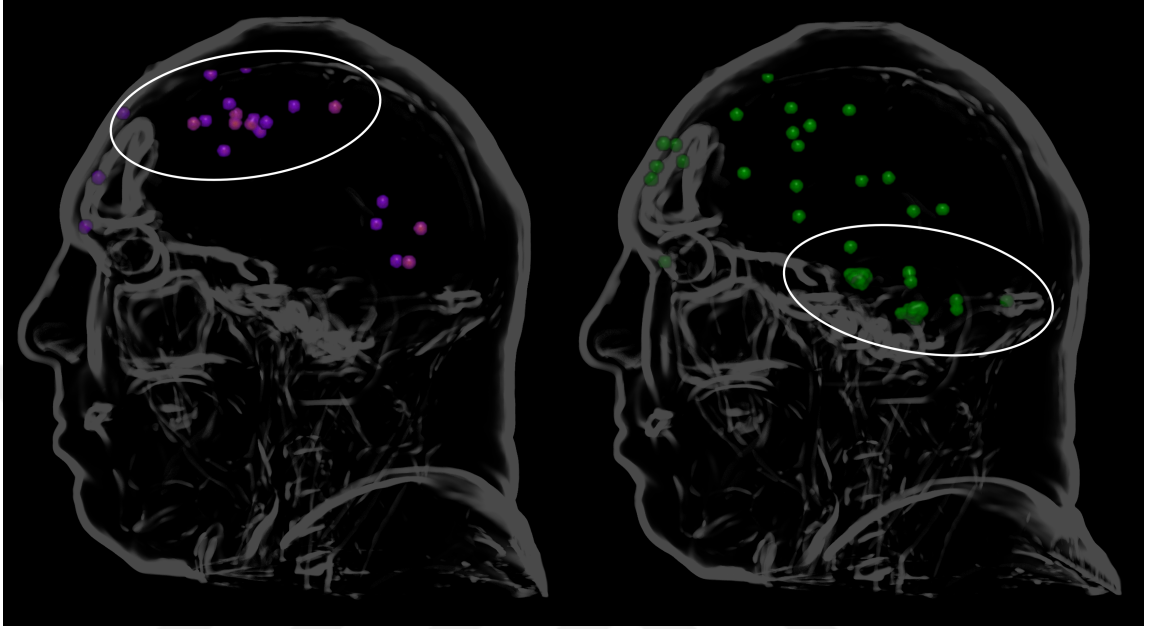


Figure 3.2: *Glass-head visualizations in blind.* *Abstract thought (on the left) and auditory imagery (on the right) markings. The areas where the two scenarios differ in intensity are marked with ellipses.*

Distance Matrices

Euclidean Distances When Euclidean distances were calculated between the centroids of all 11 scenarios, the closest distance was observed between a visual imagery and a mental arithmetic scenario ($d = 0.213$), whereas the greatest separation was observed between a visual imagery and an abstract thought scenario ($d = 2.373$).

Mahalanobis Distances In Mahalanobis distances, the closest distance was observed between two auditory imagery scenarios ($d = 0.650$), whereas the greatest separation occurred between an auditory imagery and a mental arithmetic scenario ($d = 3.689$).

Euclidean and Mahalanobis distance matrices for all scenarios are presented in Appendix C.

Global Distance Analyses

Euclidean Distances Global within-category distances ($M = 0.59$, $SD = 0.36$) were smaller than global between-category distances ($M = 1.25$, $SD = 0.52$), Welch's $t(12.80) = -4.47$, $p < .001$, $BF_{10} = 405$, indicating decisive evidence for the predicted difference.

Mahalanobis Distances Global within-category distances ($M = 1.72$, $SD = 0.81$) were smaller than global between-category distances ($M = 2.43$, $SD = 0.73$), Welch's $t(9.07) = -2.32$, $p = .046$, $BF_{10} = 2.549$, indicating a weak evidence for a difference when between-category dispersion was taken into account.

See Table 3.1 for descriptive and inferential statistics.

Table 3.1: *Global Cluster-Analysis Statistics by Euclidean and Mahalanobis Distances*

Distance	Within		Between		t	df	p	BF_{10}
	M	SD	M	SD				
Euclidean	0.59	0.36	1.25	0.52	-4.47	12.80	< .001	4.05×10^2
Mahalanobis	1.72	0.81	2.43	0.73	-2.32	9.07	.046	2.55

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Category-wise Distance Analyses

Euclidean Distances Four of the five categories showed significantly smaller within-category distances than between-category distances. Auditory imagery exhibited the largest within-category similarity relative to between-category distances, Welch's $t(1,068) = -11.75$, $p < .001$, $BF_{10} = 1.21 \times 10^{28}$. Visual imagery, abstract thought, and conscious self also yielded strong within-category similarity

relative to between-category distances.

Mahalanobis Distances The Mahalanobis analysis yielded a highly similar pattern with Euclidean distances. Auditory imagery yielded the largest within-category similarity, Welch's $t(1,100) = -12.67$, $p < .001$, $BF_{10} = 6.65 \times 10^{32}$. Visual imagery, abstract thought, and conscious self likewise demonstrated substantial within-category similarity relative to between-category distances.

See Tables 3.2 and 3.3 for descriptive and inferential statistics.

Table 3.2: *Category-wise Distance Statistics (**Euclidean**)*

Category	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought	1.55	0.92	1.92	0.96	-6.31	335.80	< .001	2.13×10^7
Auditory Imagery	1.55	1.14	2.03	0.86	-11.75	1,068.39	< .001	1.21×10^{28}
Conscious Self	1.18	0.69	1.72	0.91	-6.20	75.22	< .001	1.15×10^7
Mental Arithmetic	1.89	1.02	1.92	0.94	-0.71	621.52	= .475	0.07
Visual Imagery	1.74	0.97	2.04	0.90	-6.41	579.02	< .001	3.46×10^7

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.3: *Category-wise Distance Statistics (Mahalanobis)*

Category	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought	1.98	1.31	2.25	1.20	-3.30	321.99	= .001	14.78
Auditory Imagery	1.70	1.24	2.26	0.99	-12.68	1,100.02	< .001	6.65×10^{32}
Conscious Self	1.42	0.88	1.95	1.07	-4.74	73.45	< .001	5 836.08
Mental Arithmetic	2.28	1.39	2.24	1.20	0.59	604.42	= .555	0.06
Visual Imagery	1.94	1.11	2.30	1.06	-6.46	584.16	< .001	4.92×10^7

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Pair-wise Distance Analyses

Euclidean Distances Of ten category pairs, seven showed strong evidence of forming distinct within-category clusters when analysed together. The strongest effect was observed for the auditory–imagery and visual–imagery pair, Welch’s $t(2,426) = -11.84$, $p < .001$, $\text{BF}_{10} = 1.45 \times 10^{28}$. Similarly, abstract thought and auditory imagery, abstract thought and visual imagery, and auditory imagery and mental arithmetic pairs demonstrated robust effects.

Mahalanobis Distances The Mahalanobis analysis yielded a highly similar pattern: out of ten category pairs, five showed robust evidence of forming within-category clusters when analysed together. The largest effect was observed for the abstract-thought–auditory-imagery pair, Welch’s $t(2,134) = -11.23$, $p < .001$, $\text{BF}_{10} = 1.44 \times 10^{25}$. Auditory and visual imagery pair, along with abstract thought and visual imagery, and auditory imagery and mental arithmetic pairs, showed a strong effect of within-category clustering when paired together.

See Tables 3.4 and 3.5 for descriptive and inferential statistics.

Table 3.4: *Pair-wise Distance Statistics (**Euclidean**)*

Category Pair	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought - Auditory Imagery	1.55	1.09	2.03	0.88	-11.40	2,123.34	< .001	8.34×10^{25}
Abstract Thought - Conscious Self	1.48	0.89	1.36	0.85	1.72	618.57	= .086	0.38
Abstract Thought - Mental Arithmetic	1.76	1.00	1.76	0.97	0.09	1,537.16	= .928	0.06
Abstract Thought - Visual Imagery	1.67	0.95	2.14	0.97	-9.39	1,482.69	< .001	1.65×10^{17}
Auditory Imagery - Conscious Self	1.52	1.12	1.95	0.83	-8.28	1,297.14	< .001	1.57×10^{13}
Auditory Imagery - Mental Arithmetic	1.67	1.11	2.03	0.90	-9.34	2,599.17	< .001	1.61×10^{17}
Auditory Imagery - Visual Imagery	1.61	1.09	2.05	0.80	-11.84	2,426.92	< .001	1.45×10^{28}
Conscious Self - Mental Arithmetic	1.80	1.01	1.57	0.91	3.68	877.02	< .001	56.65
Conscious Self - Visual Imagery	1.67	0.95	1.86	0.96	-2.92	796.81	= .004	4.89
Mental Arithmetic - Visual Imagery	1.81	1.00	2.02	0.94	-4.81	1,935.22	< .001	4700.59

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.5: *Pair-wise Distance Statistics (Mahalanobis)*

Category Pair	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
Abstract Thought - Auditory Imagery	1.77	1.26	2.33	1.05	-11.23	2,134.72	< .001	1.43×10^{25}
Abstract Thought - Conscious Self	1.87	1.25	1.69	1.19	1.90	619.48	= .057	0.52
Abstract Thought - Mental Arithmetic	2.17	1.36	2.16	1.33	0.21	1,537.35	= .832	0.06
Abstract Thought - Visual Imagery	1.96	1.19	2.47	1.16	-8.35	1,482.16	< .001	2.71×10^{13}
Auditory Imagery - Conscious Self	1.68	1.22	2.07	0.87	-7.11	1,324.85	< .001	3.04×10^9
Auditory Imagery - Mental Arithmetic	1.91	1.32	2.32	1.09	-8.86	2,613.58	< .001	2.19×10^{15}
Auditory Imagery - Visual Imagery	1.78	1.20	2.23	0.86	-11.04	2,409.57	< .001	2.44×10^{24}
Conscious Self - Mental Arithmetic	2.18	1.36	1.88	1.22	3.58	880.74	< .001	38.78
Conscious Self - Visual Imagery	1.88	1.10	2.07	1.03	-2.69	830.68	= .007	2.63
Mental Arithmetic - Visual Imagery	2.12	1.27	2.34	1.18	-3.95	1,930.67	< .001	113.09

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Directional Pair-wise Distance Analyses

Euclidean Distances Of the twenty directional pair-wise comparisons, fifteen showed significant within-category clustering. The strongest effect occurred for auditory imagery when paired with visual imagery, Welch's $t(1,403) = -11.33$, $p < .001$, $BF_{10} = 3.99 \times 10^{25}$.

Mahalanobis Distances The Mahalanobis analysis closely mirrored the Euclidean pattern, adding further evidence for within-category clustering: thirteen of the twenty directional comparisons were significant. The largest effect again occurred for auditory imagery when paired with mental arithmetic, Welch's $t(1,665) = -12.14$, $p < .001$, $BF_{10} = 3.21 \times 10^{29}$.

See Tables 3.6-3.9 for descriptive and inferential statistics.

Table 3.6: *Directional Pair-wise Statistics for Abstract Thought, Auditory Imagery and Conscious Self Scenarios (**Euclidean**)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought $\rightarrow$ auditory imagery	1.55	0.92	2.03	0.88	-7.81	421.68	$< .001$	4.30×10^{11}
abstract thought $\rightarrow$ conscious self	1.55	0.92	1.36	0.85	2.54	553.46	$= .011$	2.17
abstract thought $\rightarrow$ mental arithmetic	1.55	0.92	1.76	0.97	-3.24	508.23	$= .001$	13.12
abstract thought $\rightarrow$ visual imagery	1.55	0.92	2.14	0.97	-8.92	515.66	$< .001$	2.06×10^{15}
auditory imagery $\rightarrow$ abstract thought	1.55	1.14	2.03	0.88	-10.18	1,600.03	$< .001$	2.94×10^{20}
auditory imagery $\rightarrow$ conscious self	1.55	1.14	1.95	0.83	-7.56	1,299.41	$< .001$	6.95×10^{10}
auditory imagery $\rightarrow$ mental arithmetic	1.55	1.14	2.03	0.90	-10.59	1,527.51	$< .001$	1.99×10^{22}
auditory imagery $\rightarrow$ visual imagery	1.55	1.14	2.05	0.80	-11.33	1,403.13	$< .001$	3.99×10^{25}
conscious self $\rightarrow$ abstract thought	1.18	0.69	1.36	0.85	-1.79	115.68	$= .077$	0.66
conscious self $\rightarrow$ auditory imagery	1.18	0.69	1.95	0.83	-8.36	92.16	$< .001$	9.75×10^{12}
conscious self $\rightarrow$ mental arithmetic	1.18	0.69	1.57	0.91	-4.04	108.50	$< .001$	293.78
conscious self $\rightarrow$ visual imagery	1.18	0.69	1.86	0.96	-6.90	115.31	$< .001$	3.92×10^8

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.7: *Directional Pair-wise Statistics for Mental Arithmetic and Visual Imagery Scenarios (**Euclidean**)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
mental arithmetic $\rightarrow$ abstract thought	1.89	1.02	1.76	0.97	2.17	1 018.79	$= .030$	0.66
mental arithmetic $\rightarrow$ auditory imagery	1.89	1.02	2.03	0.90	-2.85	798.06	$= .004$	3.28
mental arithmetic $\rightarrow$ conscious self	1.89	1.02	1.57	0.91	4.83	860.81	$< .001$	6.42×10^3
mental arithmetic $\rightarrow$ visual imagery	1.89	1.02	2.02	0.94	-2.56	921.76	$= .011$	1.56
visual imagery $\rightarrow$ abstract thought	1.74	0.97	2.14	0.97	-6.96	989.33	$< .001$	1.05×10^9
visual imagery $\rightarrow$ auditory imagery	1.74	0.97	2.05	0.80	-6.30	700.82	$< .001$	1.69×10^7
visual imagery $\rightarrow$ conscious self	1.74	0.97	1.86	0.96	-1.79	798.48	$= .075$	0.37
visual imagery $\rightarrow$ mental arithmetic	1.74	0.97	2.02	0.94	-5.33	884.92	$< .001$	7.12×10^4

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.8: *Directional Pair-wise Statistics for Abstract Thought, Auditory Imagery and Conscious Self Scenarios (**Ma-**
halanobis)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought $\rightarrow$ auditory imagery	1.98	1.31	2.33	1.05	-4.02	377.67	< .001	204.22
abstract thought $\rightarrow$ conscious self	1.98	1.31	1.69	1.19	2.79	551.53	= .005	4.09
abstract thought $\rightarrow$ mental arithmetic	1.98	1.31	2.16	1.33	-1.92	493.58	= .056	0.48
abstract thought $\rightarrow$ visual imagery	1.98	1.31	2.47	1.16	-5.42	446.67	< .001	1.19×10^5
auditory imagery $\rightarrow$ abstract thought	1.70	1.24	2.33	1.05	-11.76	1,694.31	< .001	3.16×10^{27}
auditory imagery $\rightarrow$ conscious self	1.70	1.24	2.07	0.87	-6.58	1,316.96	< .001	8.93×10^7
auditory imagery $\rightarrow$ mental arithmetic	1.70	1.24	2.32	1.09	-12.14	1,665.71	< .001	3.21×10^{29}
auditory imagery $\rightarrow$ visual imagery	1.70	1.24	2.23	0.86	-11.07	1,407.41	< .001	2.51×10^{24}
conscious self $\rightarrow$ abstract thought	1.42	0.88	1.69	1.19	-2.07	125.31	= .041	1.10
conscious self $\rightarrow$ auditory imagery	1.42	0.88	2.07	0.87	-5.64	82.60	< .001	3.93×10^5
conscious self $\rightarrow$ mental arithmetic	1.42	0.88	1.88	1.22	-3.64	112.37	< .001	70.61
conscious self $\rightarrow$ visual imagery	1.42	0.88	2.07	1.03	-5.36	99.07	< .001	8.77×10^4

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.9: *Directional Pair-wise Statistics for Mental Arithmetic and Visual Imagery Scenarios (Mahalanobis)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
mental arithmetic $\rightarrow$ abstract thought	2.28	1.39	2.16	1.33	1.54	1 024.75	$= .124$	0.21
mental arithmetic $\rightarrow$ auditory imagery	2.28	1.39	2.32	1.09	-0.61	733.68	$= .541$	0.07
mental arithmetic $\rightarrow$ conscious self	2.28	1.39	1.88	1.22	4.59	864.46	$< .001$	2.17×10^3
mental arithmetic $\rightarrow$ visual imagery	2.28	1.39	2.34	1.18	-0.78	864.80	$= .437$	0.08
visual imagery $\rightarrow$ abstract thought	1.94	1.11	2.47	1.16	-7.83	1 018.74	$< .001$	4.75×10^{11}
visual imagery $\rightarrow$ auditory imagery	1.94	1.11	2.23	0.86	-5.09	674.88	$< .001$	2.00×10^4
visual imagery $\rightarrow$ conscious self	1.94	1.11	2.07	1.03	-1.72	817.95	$= .086$	0.33
visual imagery $\rightarrow$ mental arithmetic	1.94	1.11	2.34	1.18	-6.17	961.25	$< .001$	7.46×10^6

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Heat Maps

When the pair-wise Euclidean-distance results were visualized, the most clearly defined within-category cluster emerged between visual imagery and auditory imagery. In addition, the abstract thought–auditory imagery pairing formed clusters that were widely separated from one another. See Figure 3.3 for details.

Visualization of the pair-wise Mahalanobis distance revealed a pattern largely parallel to the Euclidean results. The visual imagery–auditory imagery pair formed the most clear within-category clusters, followed by abstract thought–auditory imagery pairing. See Figure 3.4 for details.

When the directional pair-wise Euclidean-distance results were visualized, auditory imagery formed the most distinct cluster when paired with visual imagery. The next-strongest auditory imagery cluster were observed with mental arithmetic and abstract thought. See Figure 3.5 for details.

Visualization of the directional pair-wise Mahalanobis-distance results replicated the overall pattern observed with Euclidean distances. Auditory imagery exhibited the most distinct clustering, particularly in its pairings with mental arithmetic, abstract thought, and visual imagery sequentially. See Figure 3.6 for details.

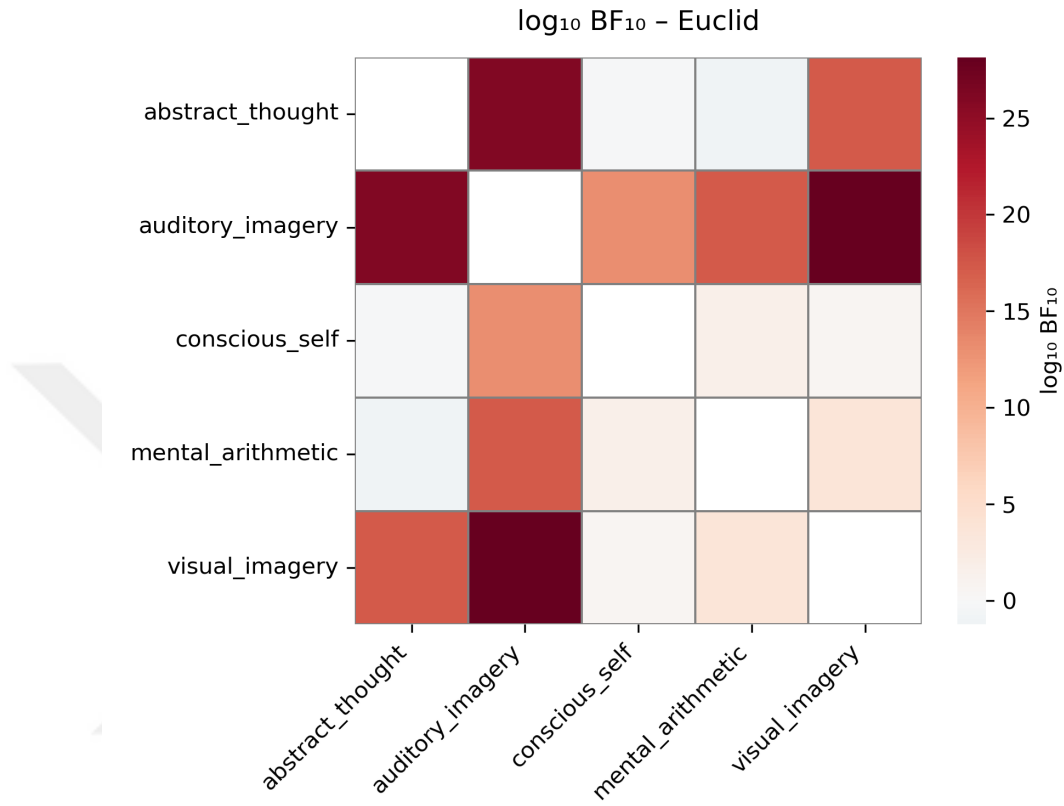


Figure 3.3: $\log_{10}BF_{10}$ *pair-wise heat map* – *Euclidean*. Dark color indicates stronger evidence for clustering - when two categories are combined, each category makes more robust clusters within itself. $\log_{10}BF_{10}$ values are used for better visualization.

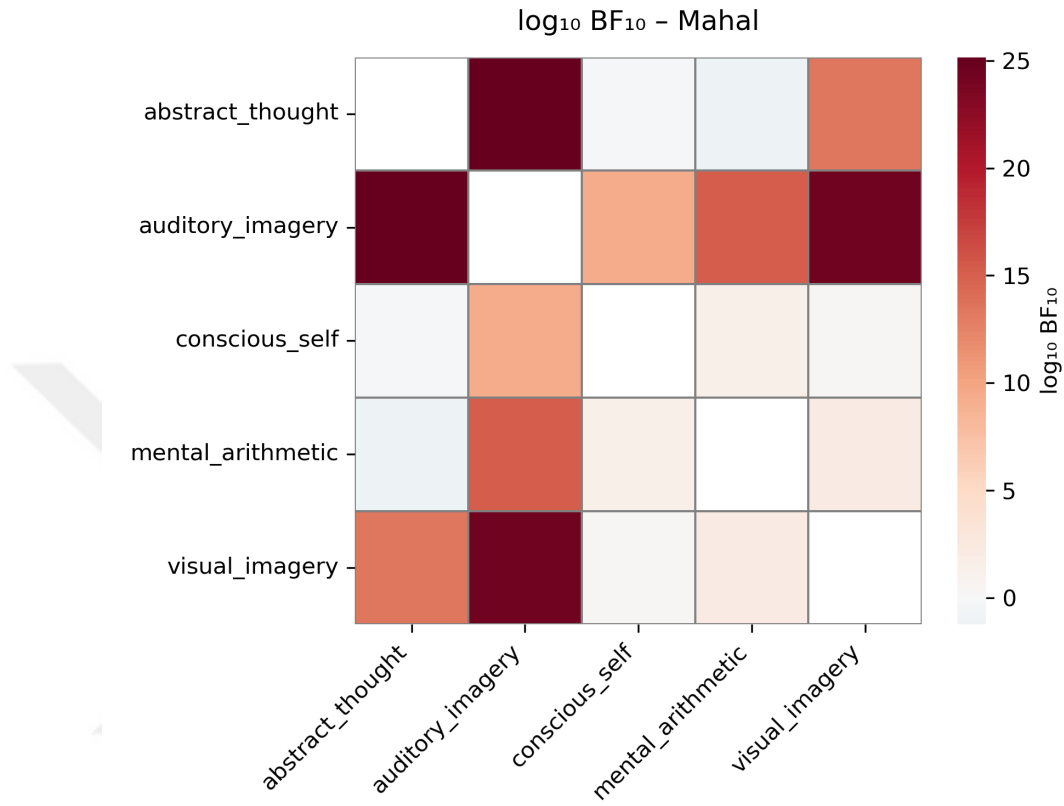


Figure 3.4: $\log_{10}BF_{10}$ *pair-wise heat map* – *Mahalanobis*. Dark color indicates stronger evidence for clustering - when two categories are combined, each category makes more robust clusters within itself. $\log_{10}BF_{10}$ values are used for better visualization.

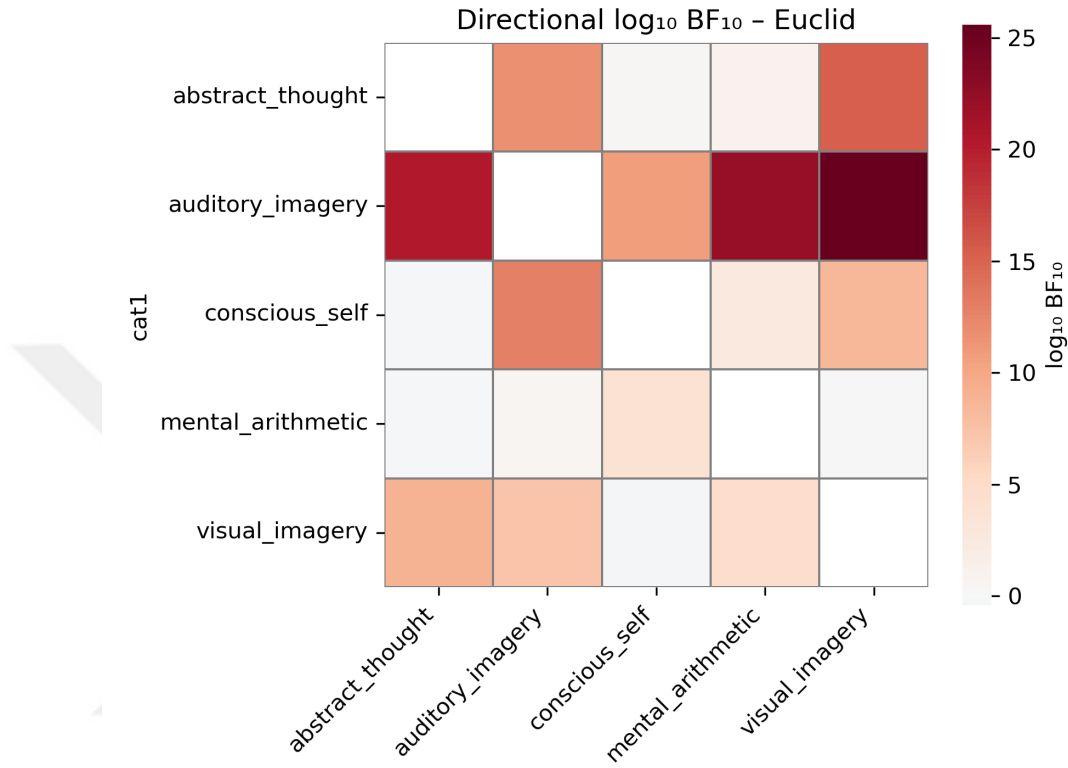


Figure 3.5: $\log_{10}BF_{10}$ *directional pair-wise heat map – Euclidean*. Dark color indicates stronger evidence for the category on the y axis, making more robust clusters within itself compared to the category it is paired with on the x axis. $\log_{10}BF_{10}$ values are used for better visualization.

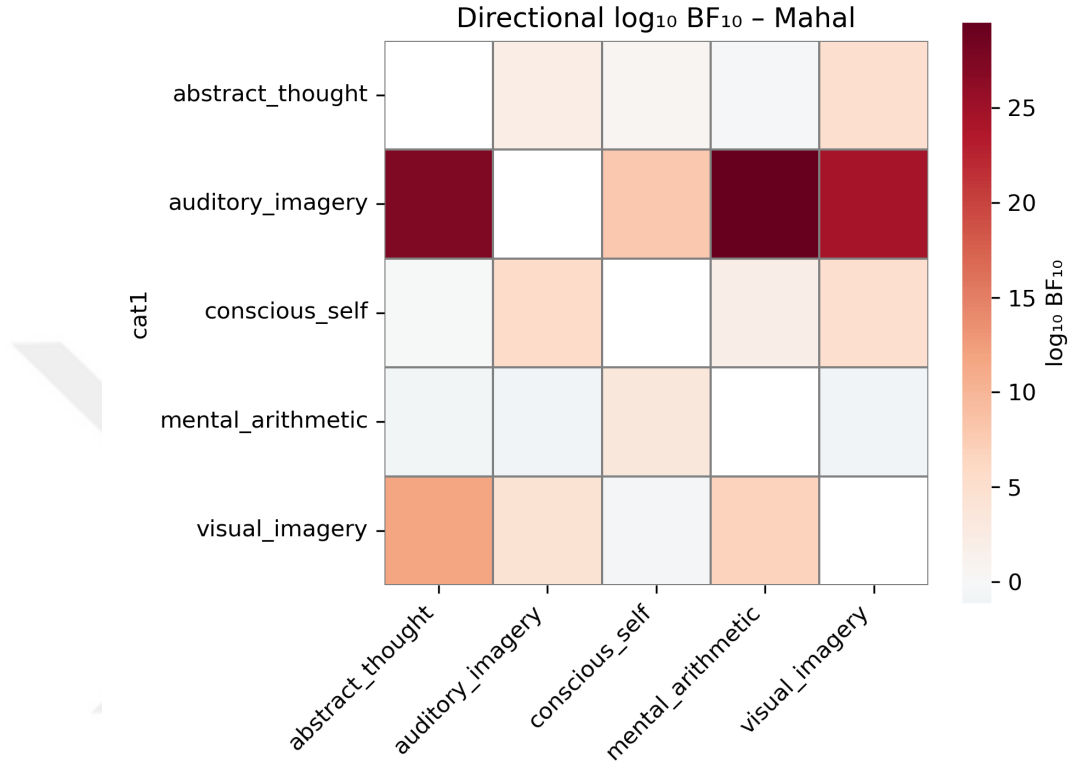


Figure 3.6: $\log_{10}BF_{10}$ *directional pair-wise heat map – Mahalanobis*. Dark color indicates stronger evidence for the category on the y axis, making more robust clusters within itself compared to the category it is paired with on the x axis. $\log_{10}BF_{10}$ values are used for better visualization.

11x11 scenario-based Euclidean and Mahalanobis heat maps are presented in Appendix D.

3.2.2 Deaf Analyses

Qualitative Visual Inspection

Visual inspection of the glass-head renderings revealed differences in spatial clustering when visual imagery and abstract thought markings were compared. Visual

imagery points were concentrated anteriorly, and abstract thoughts were clustered on the medial part (see Figure 3.7). A comparable divergence emerged between visual and auditory imagery: while visual imagery points concentrated anteriorly and around the eyes, auditory imagery points occupied the medial posterior part of the head, clustered around the ears (see Figure 3.8).

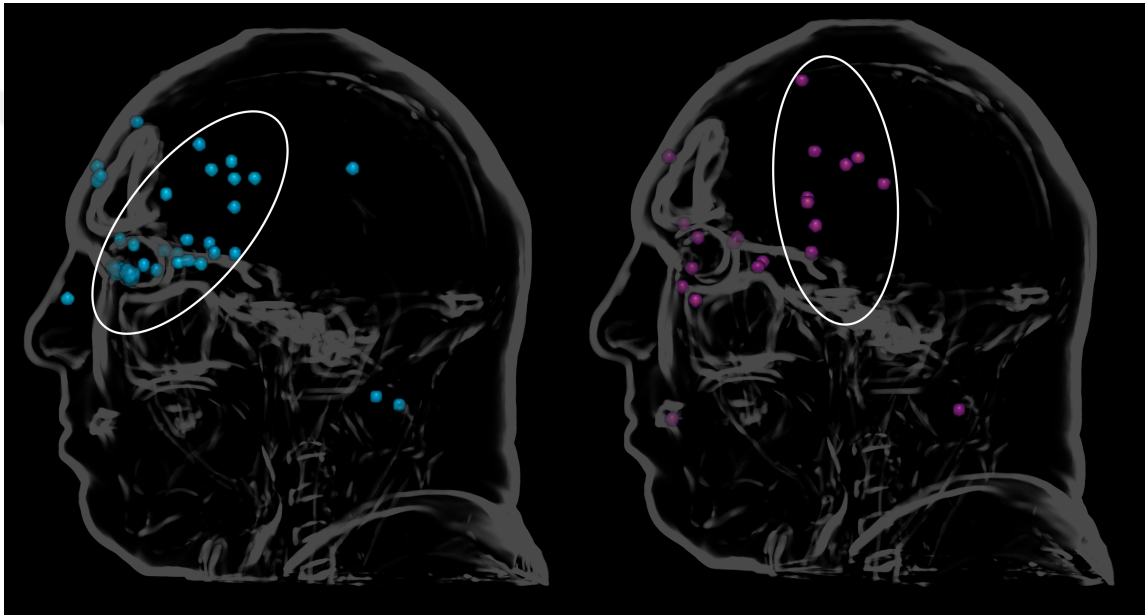


Figure 3.7: *Glass-head visualizations in deaf.* Visual imagery (on the left) and abstract thought (on the right) markings.

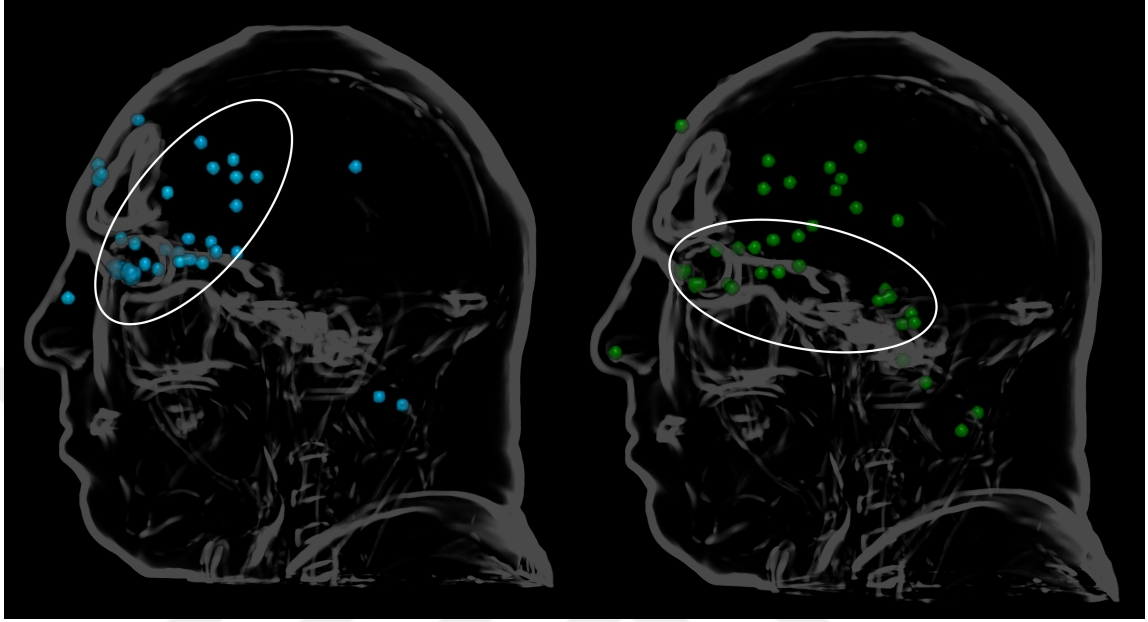


Figure 3.8: *Glass-head visualizations in deaf.* *Visual imagery (on the left) and auditory imagery (on the right) markings.*

Distance Matrices

Euclidean Distances When Euclidean distances were calculated between the centroids of all 11 scenarios, the closest distance was observed between a visual imagery and the conscious self scenario ($d = 0.169$), whereas the greatest separation was observed between a visual imagery and an auditory imagery scenario ($d = 1.975$).

Mahalanobis Distances In Mahalanobis distances, the closest distance was observed again between a visual imagery and the conscious self scenario ($d = 0.639$), whereas the greatest separation again occurred between an auditory imagery and a visual imagery scenario ($d = 4.107$).

11x11 Euclidean and Mahalanobis distance matrices for all scenarios are presented in Appendix E.

Global Distance Analyses

Euclidean Distances Global within-category distances ($M = 0.79$, $SD = 0.37$) were slightly smaller than global between-category distances ($M = 0.83$, $SD = 0.48$), Welch's $t(11.37) = -0.26$, $p = .798$, $BF_{10} = 0.365$, indicating little evidence for a difference.

Mahalanobis Distances Global within-category distances ($M = 2.23$, $SD = 0.82$) were again slightly smaller than global between-category distances ($M = 2.29$, $SD = 0.93$), Welch's $t(10.35) = -0.18$, $p = .859$, $BF_{10} = 0.361$, indicating little evidence for a difference among within- and between-category clustering.

See Table 3.10 for descriptive and inferential statistics.

Table 3.10: *Global Cluster-Analysis Statistics by Euclidean and Mahalanobis Distances*

Distance	Within		Between		t	df	p	BF_{10}
	M	SD	M	SD				
Euclidean	0.79	0.37	0.83	0.48	-0.26	11.37	.798	0.37
Mahalanobis	2.23	0.82	2.29	0.93	-0.18	10.35	.859	0.36

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Category-wise Distance Analyses

Euclidean Distances Among the five categories, two showed smaller within- than between-category distances. Visual imagery exhibited robust within-category similarity, Welch's $t(787) = -9.49$, $p < .001$, $BF_{10} = 7.19 \times 10^{17}$. Conscious self showed only a slight effect, Welch's $t(14.78) = -0.35$, $p = .729$, $BF_{10} = 0.279$.

Mahalanobis Distances The Mahalanobis analysis closely mirrored the Euclidean pattern. Visual imagery yielded robust within-category similarity, Welch's $t(798) = -11.44$, $p < .001$, $\text{BF}_{10} = 2.34 \times 10^{26}$.

See Tables 3.11 and 3.12 for descriptive and inferential statistics.



Table 3.11: *Category-wise Distance Statistics (**Euclidean**)*

Category	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought	2.38	1.12	2.19	1.11	1.76	138.23	.081	0.47
auditory imagery	2.31	1.01	2.24	1.09	1.25	682.80	.210	0.12
conscious self	1.78	1.02	1.88	1.10	-0.35	14.78	.729	0.28
mental arithmetic	2.11	1.09	2.09	1.10	0.33	354.09	.738	0.08
visual imagery	1.47	1.17	1.98	1.10	-9.49	787.16	< .001	7.19×10^{17}

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.12: *Category-wise Distance Statistics (Mahalanobis)*

Category	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought	2.59	1.13	2.34	1.13	2.34	138.15	.021	1.48
auditory imagery	2.54	1.10	2.38	1.11	2.99	655.05	.003	4.77
conscious self	1.88	0.99	1.97	1.11	-0.33	14.84	.746	0.28
mental arithmetic	2.15	1.06	2.17	1.11	-0.27	358.14	.787	0.07
visual imagery	1.45	1.14	2.05	1.10	-11.44	798.98	< .001	2.34×10^{26}

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Pair-wise Distance Analyses

Euclidean Distances Of ten category pairs, two showed strong evidence of forming distinct within-category clusters when analysed together. The strongest effect was observed for the abstract-thought-visual-imagery pair, Welch's $t(1,200) = -6.49$, $p < .001$, $BF_{10} = 5.13 \times 10^7$. Similarly, the auditory-imagery-visual-imagery pair demonstrated a strong effect, Welch's $t(2,059) = -6.09$, $p < .001$, $BF_{10} = 4.29 \times 10^6$.

Mahalanobis Distances The Mahalanobis analysis showed a similar pattern: out of ten category pairs, three provided robust evidence of forming within-category clusters when analysed together. The largest effect was observed for the abstract-thought-visual-imagery pair, Welch's $t(1,206) = -7.83$, $p < .001$, $BF_{10} = 4.55 \times 10^{11}$, followed by the auditory-imagery-visual-imagery and mental-arithmetic-visual-imagery pairs, both of which also favoured within-category clustering.

See Tables 3.13 and 3.14 for descriptive and inferential statistics.

Table 3.13: *Pair-wise Distance Statistics (**Euclidean**)*

Category Pair	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought - auditory imagery	2.32	1.03	2.31	1.08	0.22	1,032.36	.822	0.07
abstract thought - conscious self	2.31	1.12	2.08	1.07	1.59	210.69	.112	0.48
abstract thought - mental arithmetic	2.19	1.10	2.25	1.15	-0.76	774.10	.450	0.11
abstract thought - visual imagery	1.63	1.21	2.06	1.11	-6.49	1,200.10	< .001	5.13×10^7
auditory imagery - conscious self	2.29	1.01	2.19	1.06	1.17	322.42	.242	0.19
auditory imagery - mental arithmetic	2.24	1.04	2.34	1.07	-1.89	1,481.85	.059	0.34
auditory imagery - visual imagery	1.85	1.17	2.15	1.10	-6.09	2,059.06	< .001	4.29×10^6
conscious self - mental arithmetic	2.10	1.09	1.86	1.04	2.22	295.47	.027	1.20
conscious self - visual imagery	1.48	1.17	1.52	1.10	-0.38	376.66	.701	0.10
mental arithmetic - visual imagery	1.68	1.18	1.83	1.05	-2.60	1,637.62	.009	1.57

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.14: *Pair-wise Distance Statistics (Mahalanobis)*

Category Pair	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought - auditory imagery	2.55	1.10	2.51	1.15	0.58	1,034.88	.559	0.08
abstract thought - conscious self	2.51	1.14	2.23	1.06	1.92	212.68	.056	0.82
abstract thought - mental arithmetic	2.28	1.10	2.39	1.12	-1.31	776.35	.189	0.19
abstract thought - visual imagery	1.65	1.22	2.17	1.09	-7.83	1,206.90	< .001	4.55×10^{11}
auditory imagery - conscious self	2.52	1.10	2.33	1.08	2.09	341.09	.037	0.80
auditory imagery - mental arithmetic	2.40	1.10	2.47	1.08	-1.23	1,482.30	.218	0.12
auditory imagery - visual imagery	1.95	1.25	2.26	1.10	-6.10	2,033.60	< .001	4.52×10^6
conscious self - mental arithmetic	2.13	1.06	1.91	1.02	2.13	294.32	.034	1.00
conscious self - visual imagery	1.46	1.14	1.55	1.07	-1.01	375.70	.313	0.15
mental arithmetic - visual imagery	1.68	1.16	1.83	1.03	-2.86	1,636.57	.004	3.13

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Directional Pair-wise Distance Analyses

Euclidean Distances Of the twenty directional pair-wise comparisons, four showed significant within-category clustering. The strongest effect occurred for visual imagery when paired with auditory imagery, Welch's $t(1,079) = -11.40$, $p < .001$, $BF_{10} = 5.01 \times 10^{25}$.

Mahalanobis Distances The Mahalanobis analysis closely mirrored the Euclidean pattern, providing additional evidence for within-category clustering: five of the twenty directional comparisons were significant. The largest effect again occurred for visual imagery when paired with auditory imagery, Welch's $t(1,109) = -13.75$, $p < .001$, $BF_{10} = 2.13 \times 10^{37}$.

See Tables 3.15-3.18 for descriptive and inferential statistics.

Table 3.15: *Directional Pair-wise Statistics for Abstract Thought, Auditory Imagery and Conscious Self Scenarios (**Euclidean**)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract_thought → auditory_imagery	2.38	1.12	2.31	1.08	0.63	176.64	.528	0.14
abstract_thought → conscious_self	2.38	1.12	2.08	1.07	2.00	207.50	.047	0.96
abstract_thought → mental_arithmetic	2.38	1.12	2.25	1.15	1.06	203.39	.293	0.20
abstract_thought → visual_imagery	2.38	1.12	2.06	1.11	2.80	174.56	.006	4.85
auditory_imagery → abstract_thought	2.31	1.01	2.31	1.08	−0.00	958.97	.998	0.07
auditory_imagery → conscious_self	2.31	1.01	2.19	1.06	1.35	325.36	.178	0.23
auditory_imagery → mental_arithmetic	2.31	1.01	2.34	1.07	−0.52	1 033.16	.607	0.08
auditory_imagery → visual_imagery	2.31	1.01	2.15	1.10	2.65	960.66	.008	2.01
conscious_self → abstract_thought	1.78	1.02	2.08	1.07	−1.04	19.06	.310	0.44
conscious_self → auditory_imagery	1.78	1.02	2.19	1.06	−1.46	16.52	.163	0.65
conscious_self → mental_arithmetic	1.78	1.02	1.86	1.04	−0.27	17.17	.792	0.28
conscious_self → visual_imagery	1.78	1.02	1.52	1.10	0.97	16.46	.345	0.40

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.16: *Directional Pair-wise Statistics for Mental Arithmetic and Visual Imagery Scenarios (**Euclidean**)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
mental arithmetic $\rightarrow$ abstract thought	2.11	1.09	2.25	1.15	-1.61	610.51	.108	0.31
mental arithmetic $\rightarrow$ auditory imagery	2.11	1.09	2.34	1.07	-2.95	486.71	.003	5.57
mental arithmetic $\rightarrow$ conscious self	2.11	1.09	1.86	1.04	2.35	300.95	.019	1.61
mental arithmetic $\rightarrow$ visual imagery	2.11	1.09	1.83	1.05	3.82	461.20	< .001	95.40
visual imagery $\rightarrow$ abstract thought	1.47	1.17	2.06	1.11	-8.62	1 102.46	< .001	1.87×10^{14}
visual imagery $\rightarrow$ auditory imagery	1.47	1.17	2.15	1.10	-11.40	1 079.95	< .001	5.01×10^{25}
visual imagery $\rightarrow$ conscious self	1.47	1.17	1.52	1.10	-0.47	381.77	.638	0.10
visual imagery $\rightarrow$ mental arithmetic	1.47	1.17	1.83	1.05	-5.75	1 118.32	< .001	6.55×10^5

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Table 3.17: *Directional Pair-wise Statistics for Abstract Thought, Auditory Imagery and Conscious Self Scenarios (**Ma-**
halanobis)*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
abstract thought $\rightarrow$ auditory imagery	2.59	1.13	2.51	1.15	0.68	182.72	.499	0.14
abstract thought $\rightarrow$ conscious self	2.59	1.13	2.23	1.06	2.40	208.59	.017	2.17
abstract thought $\rightarrow$ mental arithmetic	2.59	1.13	2.39	1.12	1.73	196.94	.085	0.49
abstract thought $\rightarrow$ visual imagery	2.59	1.13	2.17	1.09	3.72	171.20	< .001	83.99
auditory imagery $\rightarrow$ abstract thought	2.54	1.10	2.51	1.15	0.42	958.74	.675	0.08
auditory imagery $\rightarrow$ conscious self	2.54	1.10	2.33	1.08	2.30	344.78	.022	1.26
auditory imagery $\rightarrow$ mental arithmetic	2.54	1.10	2.47	1.08	1.21	975.02	.227	0.14
auditory imagery $\rightarrow$ visual imagery	2.54	1.10	2.26	1.10	4.63	893.51	< .001	2.37×10^3
conscious self $\rightarrow$ abstract thought	1.88	0.99	2.23	1.06	-1.26	19.37	.221	0.54
conscious self $\rightarrow$ auditory imagery	1.88	0.99	2.33	1.08	-1.67	16.79	.114	0.86
conscious self $\rightarrow$ mental arithmetic	1.88	0.99	1.91	1.02	-0.11	17.24	.917	0.28
conscious self $\rightarrow$ visual imagery	1.88	0.99	1.55	1.07	1.23	16.50	.236	0.51

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are given unless $p < .001$.

Table 3.18: *Directional Pair-wise Statistics for Mental Arithmetic and Visual Imagery Scenarios*

Category Direction	M_{within}	SD_{within}	M_{between}	SD_{between}	t	df	p	BF_{10}
mental arithmetic $\rightarrow$ abstract thought	2.15	1.06	2.39	1.12	-2.79	609.85	.005	3.85
mental arithmetic $\rightarrow$ auditory imagery	2.15	1.06	2.46	1.08	-4.23	498.64	< .001	4.80×10^2
mental arithmetic $\rightarrow$ conscious self	2.15	1.06	1.91	1.02	2.24	300.08	.026	1.26
mental arithmetic $\rightarrow$ visual imagery	2.15	1.06	1.83	1.03	4.26	462.08	< .001	5.47×10^2
visual imagery $\rightarrow$ abstract thought	1.45	1.14	2.17	1.09	-10.70	1,102.83	< .001	1.77×10^{22}
visual imagery $\rightarrow$ auditory imagery	1.45	1.14	2.26	1.10	-13.75	1,109.17	< .001	2.13×10^{37}
visual imagery $\rightarrow$ conscious self	1.45	1.14	1.55	1.07	-1.13	380.49	.259	0.17
visual imagery $\rightarrow$ mental arithmetic	1.45	1.14	1.83	1.03	-6.38	1,122.55	< .001	2.66×10^7

Note. M = mean; SD = standard deviation; BF_{10} = Bayes factor in favour of H_1 over H_0 . Exact p values are reported unless $p < .001$.

Heat Maps

When the pair-wise Euclidean-distance results were visualized, the most clearly defined within-category cluster emerged between visual imagery and abstract thought. In addition, the visual imagery–auditory imagery pairing formed clusters that were widely separated from one another. See Figure 3.9 for details.

Visualization of the pair-wise Mahalanobis distance revealed a pattern largely parallel to the Euclidean results. The visual imagery–abstract thought pair formed the most clear within-category clusters, followed by visual imagery–auditory imagery pairing. See Figure 3.10 for details.

When the directional pair-wise Euclidean-distance results were visualized, visual imagery formed the most distinct cluster when paired with auditory imagery. The next-strongest cluster was again observed in visual imagery when paired with abstract thought. See Figure 3.11 for details.

Visualization of the directional pair-wise Mahalanobis-distance results replicated the overall pattern observed with Euclidean distances. Visual imagery exhibited the most distinct clustering, particularly in its pairings with auditory imagery and abstract thought sequentially. See Figure 3.12 for details.

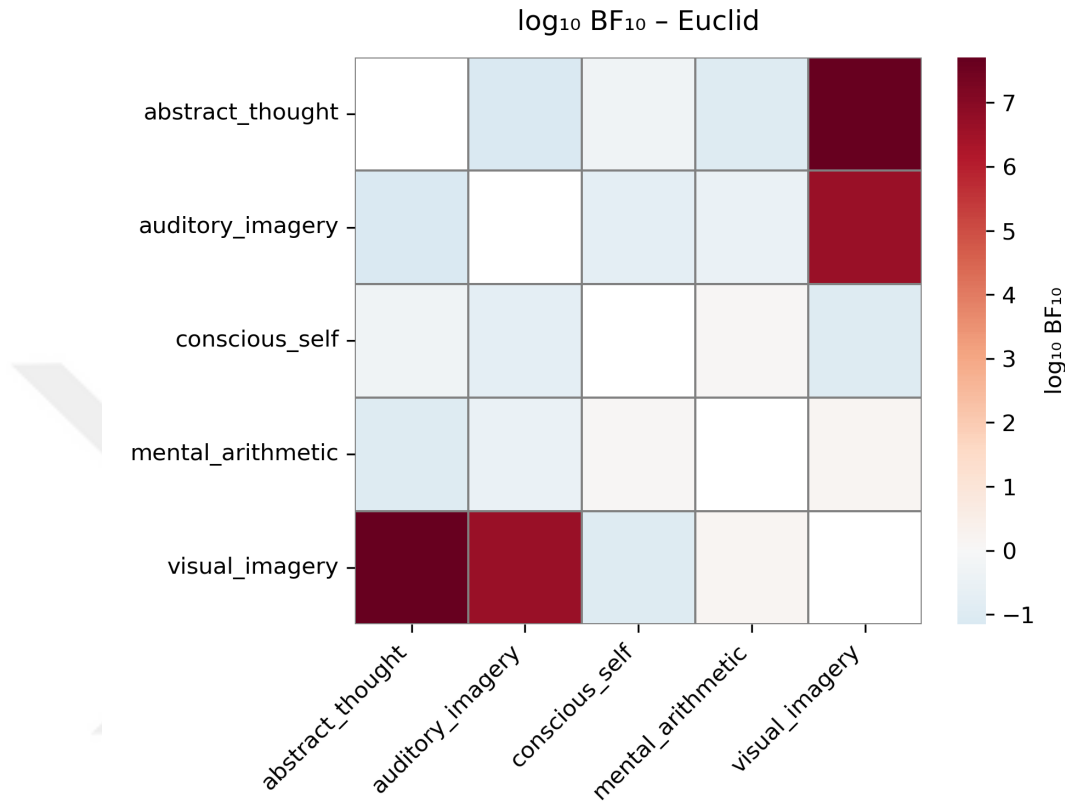


Figure 3.9: $\log_{10}BF_{10}$ *pair-wise heat map* – *Euclidean*. Dark color indicates stronger evidence for clustering - when two categories are combined, each category makes more robust clusters within itself. $\log_{10}BF_{10}$ values are used for better visualization.

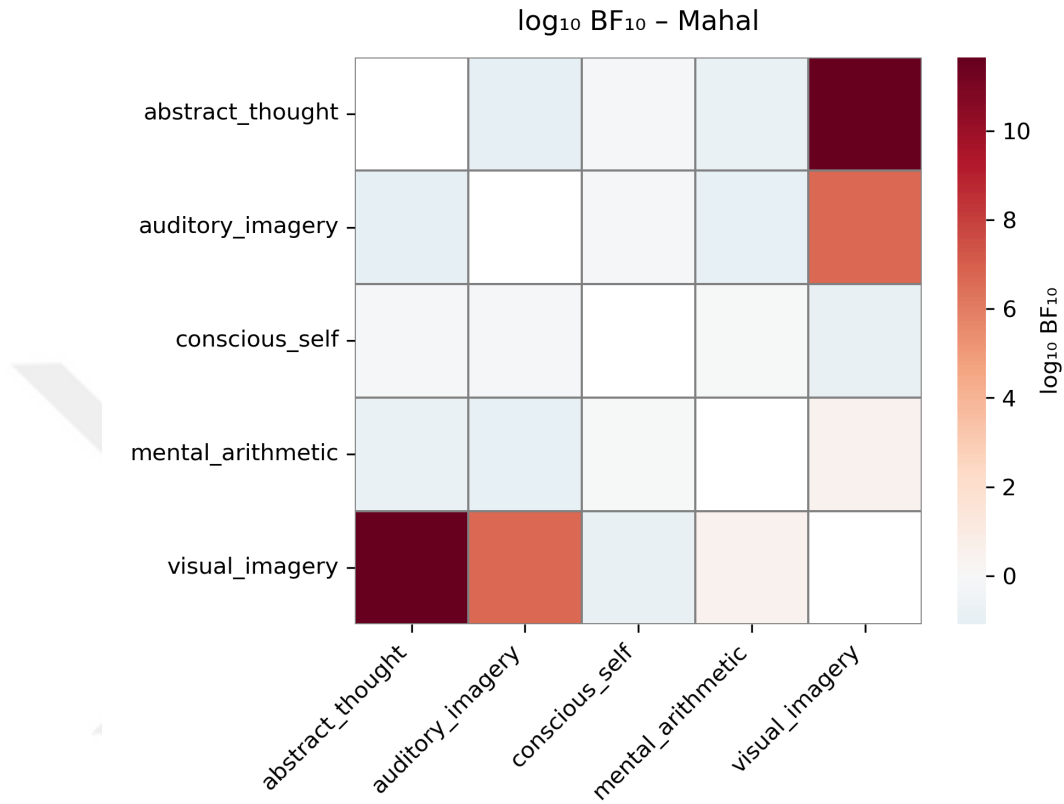


Figure 3.10: $\log_{10}BF_{10}$ *pair-wise heat map* – Mahalanobis. Dark color indicates stronger evidence for clustering - when two categories are combined, each category makes more robust clusters within itself. $\log_{10}BF_{10}$ values are used for better visualization.

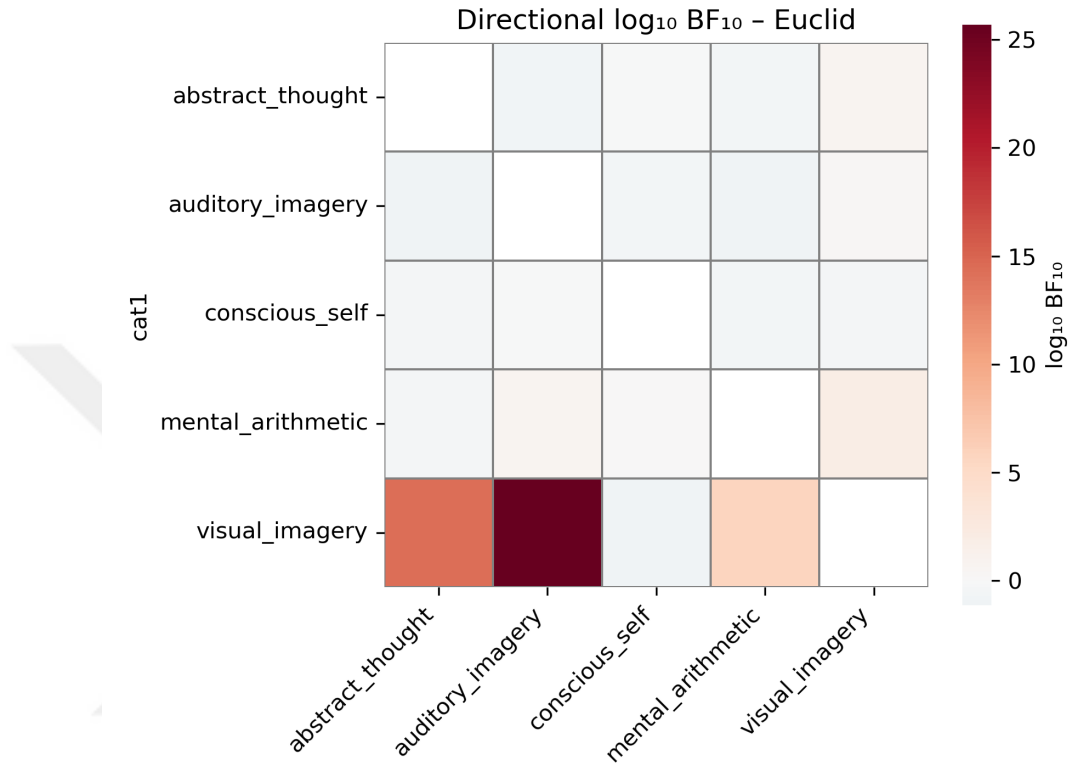


Figure 3.11: $\log_{10} BF_{10}$ *directional pair-wise heat map – Euclidean.* Dark color indicates stronger evidence for the category on the y axis, making more robust clusters within itself compared to the category it is paired with on the x axis. $\log_{10} BF_{10}$ values are used for better visualization.

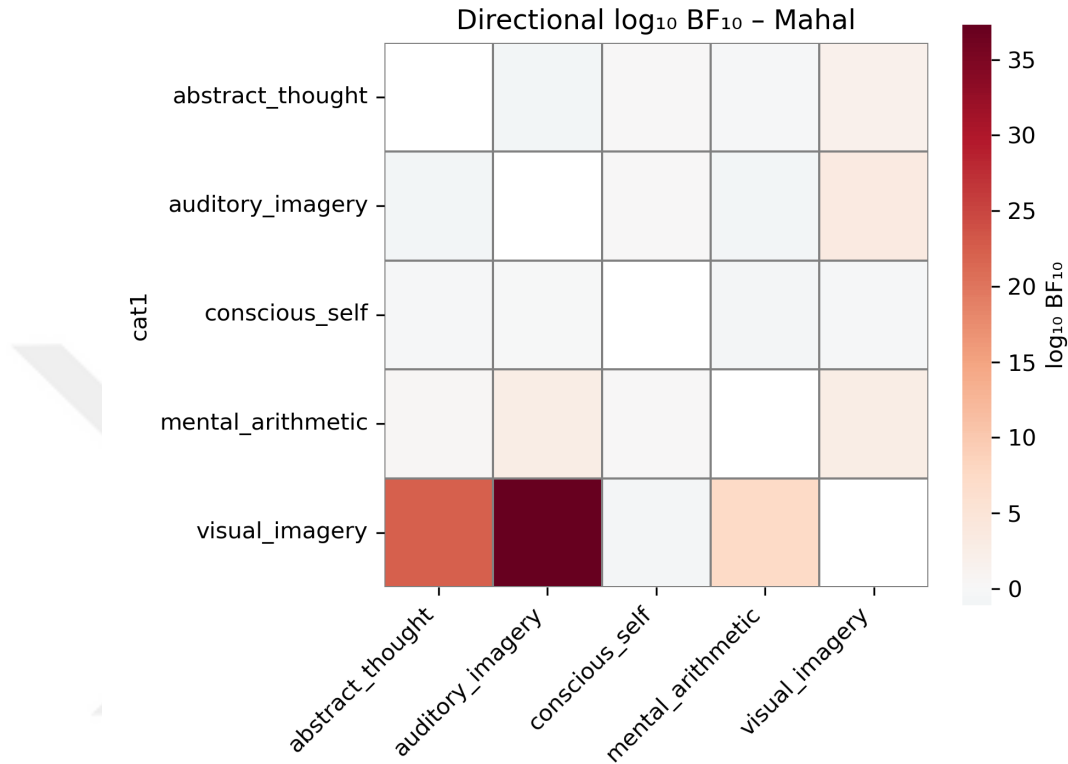


Figure 3.12: $\log_{10}BF_{10}$ *directional pair-wise heat map – Mahalanobis*. Dark color indicates stronger evidence for the category on the y axis, making more robust clusters within itself compared to the category it is paired with on the x axis. $\log_{10}BF_{10}$ values are used for better visualization.

11x11 scenario-based Euclidean and Mahalanobis heat maps are presented in Appendix F.

3.3 Discussion

In blind participants, as in sighted individuals, scenarios generally clustered by category; yet the high variability within several categories reduced the strength of this pattern once within-category variance was considered. All categories except mental arithmetic still formed clear, private clusters relative to the others, with

auditory imagery exhibiting the strongest grouping.

Auditory imagery consistently formed a close, discrete cluster, standing apart from every other category. Abstract thought split cleanly from auditory and visual imagery, but when paired with conscious self or mental arithmetic, those three blurred into a tangled, overlapping pattern. Visual imagery, in contrast, stayed well separated from every category it was put together with. Overall, abstract thought, mental arithmetic, and conscious self didn't act the same way each time: sometimes they formed separate groups, other times they mixed together, and conscious self tended to group most closely with mental arithmetic.

When we compared each pair of categories, we looked at how closely each one grouped on its own. Auditory imagery grouped distinctly every time, and conscious self and visual imagery also stayed close together within themselves, so all three stood apart from the categories they were paired with. Abstract thought grouped well in some pairs but not others. Mental arithmetic never formed a distinct, separate group, so it never stood apart from the other category it paired.

Among deaf participants, we saw little evidence of separate clusters. Distances within a category were the same as distances between categories, so the patterns all blended together instead of forming the clear groupings we saw in sighted-hearing and blind groups. The only exception was visual imagery, which still formed a strong, tight cluster of its own, while the other categories remained scattered.

Visual imagery showed a clear distinction; it formed a tight, separate group when paired with either auditory imagery or abstract thought. In all other pairings, the categories blended together and did not cluster more closely within themselves than with each other. This strong within-category clustering came mainly from visual imagery, which formed a very tight group.

Analyses show that the cluster structure is preserved in blind people but not in deaf people. It can be interpreted that visual ability does not change how we experience thoughts. However, the same may not be true for auditory ability.

Auditory ability may play a role in the distinct positioning of thoughts and images in the body.

Another inference could be that the strong and distinct separation of the visual imagery category observed in deaf participants may indicate that these individuals place a heavy emphasis on their visual abilities.

The loss of distinct clustering in deaf individuals but its preservation in blind individuals may indicate that our ability to distinctly locate thoughts within our own bodies is influenced by the absence of certain sensory modalities. Embodied cognition research should take sensory modality into account in studies. The loss of a sensory modality may alter, weaken, or delegate embodied cognition, specifically the localization of thoughts in the body, to different modalities.

Chapter 4

General Discussion

In this study, we addressed two main questions: Are thoughts located in the body template? And if so, are different thoughts located in different ways? To answer these questions, we conducted two studies. Experiment 1 examined how thoughts and images in five different categories were located on the body template. Experiment 2 examined the effect of visual and auditory loss on the location of different thought categories on the body template. Overall, the findings pointed to three main takeaways: 1) People do locate thoughts and images on their body templates, 2) Different thoughts are located differently on the body template, 3) This bodily map of thought looks much the same in blind individuals, but it fades in deaf individuals —except that their visual-imagery spot becomes even clearer.

Thoughts are embodied and spatially distinct, but not all thoughts have clear embodied loci to the same degree. People locate mental arithmetic and auditory thoughts very distinctly and separately from other thoughts in their bodies. They also place visual imagery and auditory imagery as distinctly different groups, making the difference between these two forms especially sharp.

In blind individuals, auditory imagery emerged as the most sharply defined category on the head template, with conscious self and visual imagery also appearing

in clear, separate groups. Notably, the loss of vision did not reduce the spatial precision of visual imagery; blind participants mapped visual thoughts as distinctly as sighted-hearing controls. This suggests that visual deprivation, by itself, does not weaken embodied representations of visual thought. However, in blind individuals, we observed an increased distinctness of auditory imagery, indicating a greater reliance on—or salience of—auditory thoughts in the absence of visual input.

Among deaf individuals, the overall bodily map of thought was largely disrupted: most categories no longer formed the tight clusters seen in sighted-hearing and blind groups, and the different thoughts were scattered across the template. Yet, visual imagery remained clearly defined and formed a distinct group. This pattern suggests that auditory deprivation may lead to a compensatory sharpening of visual representations. Visual thoughts become more distinctly localized, even though the broader clustering structure breaks down.

Categories that rely on external input were located in the body associated with their sensory channels. Participants placed auditory thoughts near the ears and visual thoughts near the eyes. This pattern suggests that the bodily map of thought may be linked to the sensory pathways. Imagining a sound or an image could trigger activation of the neural and even muscular systems used for hearing or seeing, creating a localized sensation in those areas. Physiological studies will be needed to confirm this mechanism.

This study has several limitations. First, the scenarios were deliberately written rich to help participants imagine them, but that extra detail may have introduced unintended emotional cues. For example, the scenario about “listening to birds and animals in a forest” could inspire a sense of calm; a participant who feels that calm in the chest might mark the chest area rather than the ears. Such emotion-driven placements could add noise to the clustering patterns. Future experiments should use differently phrased versions of each scenario to see whether the clusters become sharper. Second, in the scope of this thesis study, we only analyzed the locations on the head template. Results of the mappings in the entire body could reveal additional, possibly more distinct, spatial patterns. Follow-up work using

full-body templates will be necessary to determine how generalizable the present findings are.

Based on these findings, various implications for practical applications can also be developed. A technique developed based on the findings of this study can be applied to children with attention deficit hyperactivity disorder (ADHD) who have difficulty sustaining attention while thinking about and performing tasks [32]. This technique aims to help them regain their focus when their attention wanders. In practice, therapists can guide individuals with attention deficits to intentionally focus their thoughts on specific body parts while engaged in a task. By mentally anchoring their thoughts to these designated “body points,” this process can make their thoughts more concrete and repeatedly draw their attention back to the physical focus of the task, thereby supporting and strengthening their ability to sustain concentration.

People with obsessive-compulsive disorder (OCD) are often trapped in thought loops and repeatedly return to the same obsessive thoughts [33]. For such individuals, deliberately shifting to alternative thoughts and concretizing these thoughts by assigning them to specific body parts may be a way to reduce the dominance of obsessive thoughts. For example, a person might focus on their eye area and imagine looking at a calming painting, or concentrate on their ears and imagine listening to the soft sounds of animals in the forest. As new thoughts materialize in the body, obsessive thoughts begin to lose their hold. Alternatively, individuals can learn to locate their obsessive thoughts in specific body parts, concretize them, and then gradually reshape or reassign them—ultimately reducing their intensity or even eliminating them entirely.

Research on bodily maps of emotions has shown that these maps appear weakened and blurred in individuals with schizophrenia or bilateral vestibulopathy compared to control groups [25, 27]. In our study, we similarly observed that bodily maps of thoughts are diminished in the deaf population. If future research confirms that bodily maps of thoughts are also disrupted in other clinical populations, this altered or weakened embodiment of thoughts could potentially serve as a diagnostic marker. Specifically, it could be incorporated into neuropsychological

assessments as a test to support the diagnosis of clinical cases.

In patients recovering from stroke or traumatic brain injury, therapists could design practices that anchor tasks involving thinking and planning to specific bodily areas, enabling patients to actualize their thoughts, perceive them more clearly, and translate them into action. Such practices may facilitate and potentially accelerate the recovery of cognitive functions in individuals undergoing neurorehabilitation.

In the rehabilitation of blind and deaf individuals, the sharpened sensory modality (i.e., audition in the blind and vision in the deaf) can be further amplified. Importantly, because blind individuals retain the localization of most types of thoughts while deaf individuals lose much of this mapping, rehabilitation strategies should differ: for the blind, a broader range of approaches may be beneficial, whereas for the deaf, interventions should place stronger emphasis on vision. Existing tactile and visual substitution devices (e.g., BrainPort, vOICe) typically deliver input through the tongue, back, or hands [34], yet these channels do not necessarily align with the natural bodily loci where people localize corresponding thoughts. Our findings showed that visual thoughts tend to cluster near the eyes and auditory thoughts near the ears. Future substitution devices could utilize this mapping by stimulating these precise body regions—for example, glasses with micro-vibrators positioned around the eyes to deliver “visual” substitution signals, or ear-cuff devices with vibrotactile input to provide “auditory” substitution. Anchoring substitution signals in the body’s natural map may render the experience more intuitive and reduce the cognitive load required during adaptation.

Taken together, the present study provides the first systematic evidence that people do not experience their thinking as purely abstract but instead locate several types of thought in specific bodily locations, in the head. Across two experiments, we first showed that sighted-hearing individuals map different thought categories in their heads separately from each other; second, that this spatial map is largely preserved in blind individuals but lost in deaf individuals, except

for a pronounced sharpening of visual imagery. These patterns show that sensory experience provides a framework for mental localization: if a modality is not present, the thoughts normally associated with it lose their spatial basis, while the remaining modality may become more pronounced. The finding that auditory and visual thoughts cluster around the ears and eyes, respectively, further supports the idea that imagining activates the same sensorimotor systems that support perception. Within these bounds, the current study advances the field by extending the theory of embodied cognition to include the subjective localization of thought.

Bibliography

- [1] E. H. F. de Haan and H. C. Dijkerman. “Somatosensation in the brain: a theoretical re-evaluation and a new model”. *Trends in Cognitive Sciences* 24.7 (2020), pp. 529–541. DOI: 10.1016/j.tics.2020.04.003.
- [2] M. Botvinick and J. Cohen. “Rubber hands ‘feel’ touch that eyes see”. *Nature* 391.6669 (1998), p. 756. DOI: 10.1038/35784.
- [3] J. Limanowski and H. Hecht. “Where do we stand on locating the self?”. *Psychology* 2.4 (2011), pp. 312–317. DOI: 10.4236/psych.2011.24049.
- [4] C. Starmans and P. Bloom. “Windows to the soul: Children and adults see the eyes as the location of the self”. *Cognition* 123.2 (2012), pp. 313–318. DOI: 10.1016/j.cognition.2012.02.002.
- [5] S. Schäfer et al. “The natural egocenter: An experimental account of locating the self”. *Consciousness and Cognition* 74 (2019), p. 102775. DOI: 10.1016/j.concog.2019.102775.
- [6] A. J. T. Alsmith and M. R. Longo. “Where exactly am I? Self-location judgements distribute between head and torso”. *Consciousness and Cognition* 24 (2014), pp. 70–74. DOI: 10.1016/j.concog.2013.12.005.
- [7] A. W. Hanley, N. Lecy, and R. Hanley. “Locating the embodied sense of self and examining its relationship with psychological well-being”. *International Journal of Transpersonal Studies* 40.1 (2021), pp. 84–95. DOI: 10.24972/ijts.2021.40.1.84.

- [8] A. K. Fetterman and M. D. Robinson. “Do you use your head or follow your heart? Self-location predicts personality, emotion, decision making, and performance”. *Journal of Personality and Social Psychology* 105.2 (2013), pp. 316–334. DOI: 10.1037/a0033374.
- [9] M. Sester. “When the self dwells in the heart: How a heart-located attentional stance facilitates a felt sense of connection”. ProQuest No. 30988319. Doctoral dissertation. San Francisco, CA: California Institute of Integral Studies, 2024.
- [10] M. Dambrun et al. “Changes in self-location during the practice of mindfulness meditation in novices”. *Mindfulness* 14.1 (2023), pp. 174–191. DOI: 10.1007/s12671-022-02042-y.
- [11] R. L. Irvin et al. “Heads of Worry, Hearts of Joy: Daily Diary Investigations of Self-Location and Well-Being”. *Affective Science* 4.4 (2023), pp. 744–756. DOI: 10.1007/s42761-023-00196-z.
- [12] M. A. Friehs, S. Schäfer, and C. Frings. “The (Gami)fictional Ego-Center: Projecting the Location of the Self into an Avatar”. *Frontiers in Psychology* 13 (2022), p. 918688. DOI: 10.3389/fpsyg.2022.918688.
- [13] W. James. “What is emotion? 1884.” (1948).
- [14] R. Jerath and C. Beveridge. “Respiratory rhythm, autonomic modulation, and the spectrum of emotions: the future of emotion recognition and modulation”. *Frontiers in psychology* 11 (2020), p. 1980.
- [15] A. Damasio and G. B. Carvalho. “The nature of feelings: evolutionary and neurobiological origins”. *Nature reviews neuroscience* 14.2 (2013), pp. 143–152.
- [16] E. F. Pace-Schott et al. “Physiological feelings”. *Neuroscience & Biobehavioral Reviews* 103 (2019), pp. 267–304.
- [17] Z. Kövecses. *Metaphor and emotion: Language, culture, and body in human feeling*. Cambridge University Press, 2003.
- [18] L. Nummenmaa et al. “Bodily maps of emotions”. *Proceedings of the National Academy of Sciences* 111.2 (2014), pp. 646–651.

- [19] W.-M. Jung et al. “Role of interoceptive accuracy in topographical changes in emotion-induced bodily sensations”. *PloS one* 12.9 (2017), e0183211.
- [20] M. Giraud, M. Marelli, and E. Nava. “Embodied language of emotions: Predicting human intuitions with linguistic distributions in blind and sighted individuals”. *Heliyon* 9.7 (2023).
- [21] M. Hartmann, B. Lenggenhager, and K. Stocker. “Happiness feels light and sadness feels heavy: introducing valence-related bodily sensation maps of emotions”. *Psychological research* 87.1 (2023), pp. 59–83.
- [22] J. M. Lahnakoski et al. “Embodied emotions in ancient Neo-Assyrian texts revealed by bodily mapping of emotional semantics”. *iScience* 27.12 (2024).
- [23] V. Putkinen et al. “Bodily maps of musical sensations across cultures”. *Proceedings of the National Academy of Sciences* 121.5 (2024), e2308859121.
- [24] O. Blazhenkova and K. Dogerlioglu-Demir. “The shape of the pill: Perceived effects, evoked bodily sensations and emotions”. *Plos one* 15.9 (2020), e0238378.
- [25] L. J. Torregrossa et al. “Anomalous bodily maps of emotions in schizophrenia”. *Schizophrenia bulletin* 45.5 (2019), pp. 1060–1067.
- [26] S. Wainio-Theberge and J. L. Armony. “Antisocial and impulsive personality traits are linked to individual differences in somatosensory maps of emotion”. *Scientific reports* 13.1 (2023), p. 675.
- [27] E. Nakul et al. “Body-maps of emotions in bilateral vestibulopathy”. *Journal of neurology* 267.Suppl 1 (2020), pp. 104–108.
- [28] M. Giraud et al. “Mapping the emotional homunculus with fMRI”. *iScience* 27.6 (2024).
- [29] G. Novembre et al. “Bodily sensations in social scenarios: Where in the body?” *PLOS ONE* 14.6 (2019), e0206270. DOI: 10.1371/journal.pone.0206270.
- [30] A. M. Herman et al. “The utility of the emBODY tool as a novel method of studying complex phenomena-related emotions”. *Scientific Reports* 12.1 (2022), p. 19884. DOI: 10.1038/s41598-022-23734-4.

- [31] L. Nummenmaa et al. “Maps of subjective feelings”. *Proceedings of the National Academy of Sciences* 115.37 (2018), pp. 9198–9203. DOI: 10.1073/pnas.1807390115.
- [32] V. I. Douglas. “Stop, look and listen: The problem of sustained attention and impulse control in hyperactive and normal children”. *Canadian Journal of Behavioural Science/Revue canadienne des sciences du comportement* 4.4 (1972), pp. 259–282. DOI: 10.1037/h0082313.
- [33] A. M. Graybiel and S. L. Rauch. “Toward a neurobiology of obsessive-compulsive disorder”. *Neuron* 28.2 (2000), pp. 343–347. DOI: 10.1016/S0896-6273(00)00113-6.
- [34] M. Vincent et al. “Shape discrimination using the tongue: Implications for a visual-to-tactile sensory substitution device”. *Multisensory Research* 29.8 (2016), pp. 773–798. DOI: 10.1163/22134808-00002542.

Appendix A

Distance Matrices

Table A.1: *Euclidean distances among all 11 scenarios*

	A1	A2	A3	AT1	AT2	CS	MA1	MA2	V1	V2	V3
A1	–										
A2	0.277	–									
A3	0.376	0.123	–								
AT1	0.254	0.439	0.504	–							
AT2	0.375	0.519	0.604	0.252	–						
CS	0.400	0.608	0.659	0.209	0.418	–					
MA1	0.589	0.803	0.859	0.366	0.463	0.229	–				
MA2	0.562	0.779	0.845	0.343	0.384	0.265	0.106	–			
V1	0.526	0.720	0.801	0.341	0.225	0.394	0.323	0.221	–		
V2	0.527	0.676	0.792	0.556	0.372	0.699	0.730	0.637	0.455	–	
V3	0.409	0.643	0.736	0.281	0.230	0.339	0.341	0.256	0.169	0.392	–

Note. Smaller values indicate greater similarity.

Table A.2: Mahalanobis distances among all 11 scenarios

	A1	A2	A3	AT1	AT2	CS	MA1	MA2	V1	V2	V3
A1	–										
A2	2.046	–									
A3	2.857	0.889	–								
AT1	2.063	1.537	1.864	–							
AT2	3.513	2.353	2.382	1.848	–						
CS	1.824	2.467	2.883	1.376	3.149	–					
MA1	2.687	2.860	3.118	1.351	2.614	1.125	–				
MA2	2.717	2.701	2.981	1.180	2.084	1.504	0.609	–			
V1	3.420	2.735	2.890	1.727	0.861	2.786	2.048	1.462	–		
V2	2.720	3.113	3.850	3.016	2.933	3.612	3.650	3.223	2.873	–	
V3	1.728	2.431	3.103	1.532	2.444	1.747	1.787	1.510	2.042	1.942	–

Note. Smaller values indicate greater similarity.

Appendix B

Scenario-Based Heat Maps

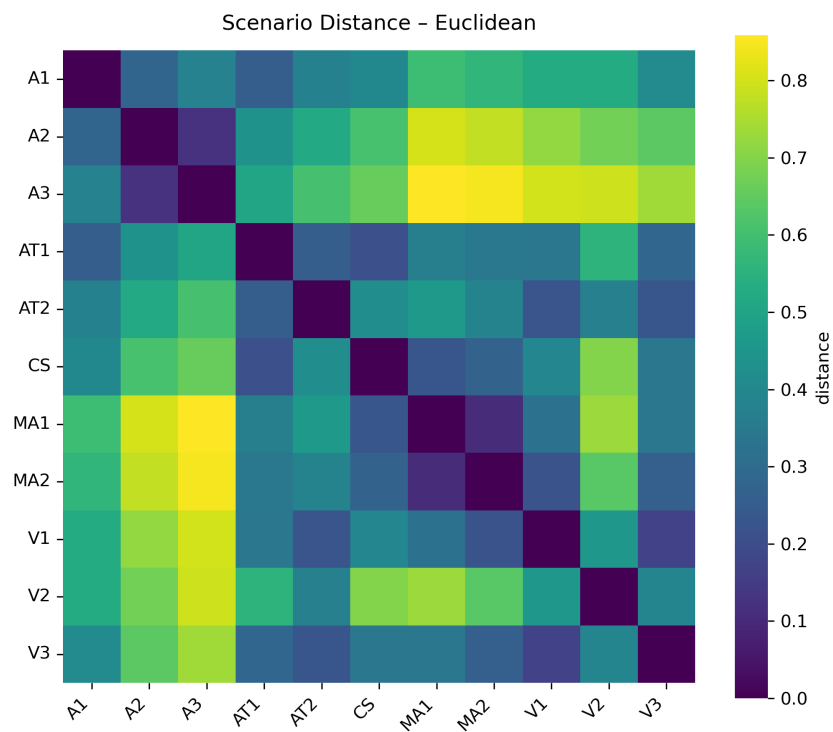


Figure B.1: Scenario-based heat map – Euclidean. In the heat-map legend, dark/navy blue cells indicate high similarity—that is, a small Euclidean distance, suggesting the two scenarios fall within the same cluster—whereas yellow cells mark low similarity, reflecting large distances and implying the scenarios belong to separate clusters.

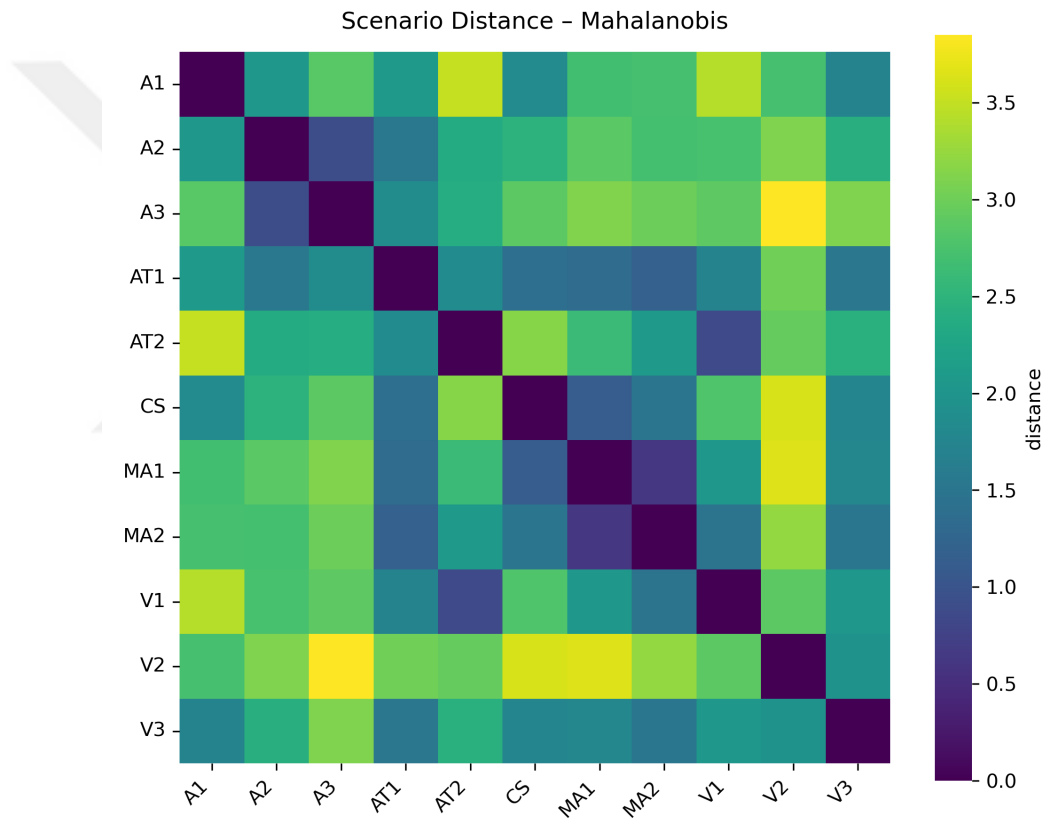


Figure B.2: Scenario-based heat map – Mahalanobis. In the heat-map legend, dark/navy blue cells indicate high similarity—that is, a small Mahalanobis distance, suggesting the two scenarios fall within the same cluster—whereas yellow cells mark low similarity, reflecting large distances and implying the scenarios belong to separate clusters.

Appendix C

Distance Matrices (Blind Data)

Table C.1: *Euclidean Distances Among All 11 Scenarios*

	A1	A2	A3	AT1	AT2	CS	MA1	MA2	V1	V2	V3
A1	–										
A2	0.262	–									
A3	0.344	0.280	–								
AT1	1.586	1.348	1.528	–							
AT2	1.643	1.447	1.666	0.453	–						
CS	1.656	1.402	1.538	0.293	0.732	–					
MA1	1.461	1.225	1.415	0.153	0.487	0.363	–				
MA2	1.080	0.822	0.899	0.823	1.159	0.731	0.728	–			
V1	1.590	1.391	1.330	1.551	1.955	1.361	1.479	0.851	–		
V2	2.085	1.894	1.813	1.941	2.373	1.714	1.891	1.328	0.509	–	
V3	1.283	1.022	1.095	0.723	1.112	0.569	0.659	0.213	0.864	1.297	–

Note. Smaller values indicate greater similarity.

Table C.2: Mahalanobis Distances Among All 11 Scenarios

	A1	A2	A3	AT1	AT2	CS	MA1	MA2	V1	V2	V3
A1	–										
A2	0.650	–									
A3	2.593	2.102	–								
AT1	2.725	2.226	3.039	–							
AT2	2.655	2.279	3.362	0.779	–						
CS	3.640	3.003	2.541	1.664	2.260	–					
MA1	2.438	2.174	3.689	1.153	1.057	2.789	–				
MA2	2.189	1.569	2.007	1.328	1.899	1.633	1.918	–			
V1	2.598	2.267	3.247	2.385	2.911	3.018	2.244	1.677	–		
V2	3.420	3.036	3.557	2.892	3.538	3.130	2.957	2.138	0.903	–	
V3	2.996	2.348	1.898	1.694	2.344	0.925	2.623	0.930	2.329	2.481	–

Note. Smaller values indicate greater similarity.

Appendix D

Scenario Heat Maps (Blind Data)

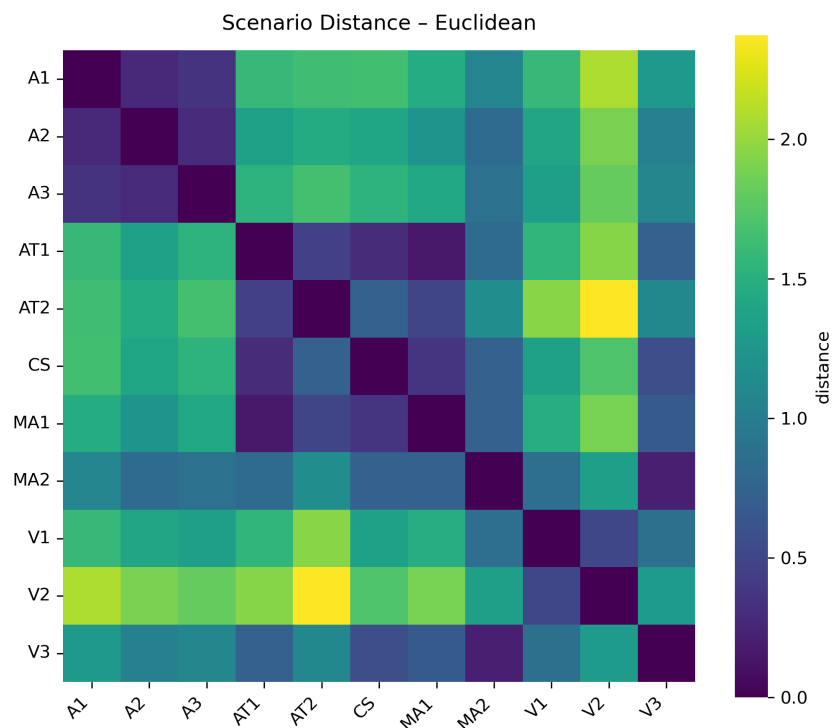


Figure D.1: Scenario-based heat map – Euclidean. In the heat-map legend, dark/navy blue cells indicate high similarity—that is, a small Euclidean distance, suggesting the two scenarios fall within the same cluster—whereas yellow cells mark low similarity, reflecting large distances and implying the scenarios belong to separate clusters.

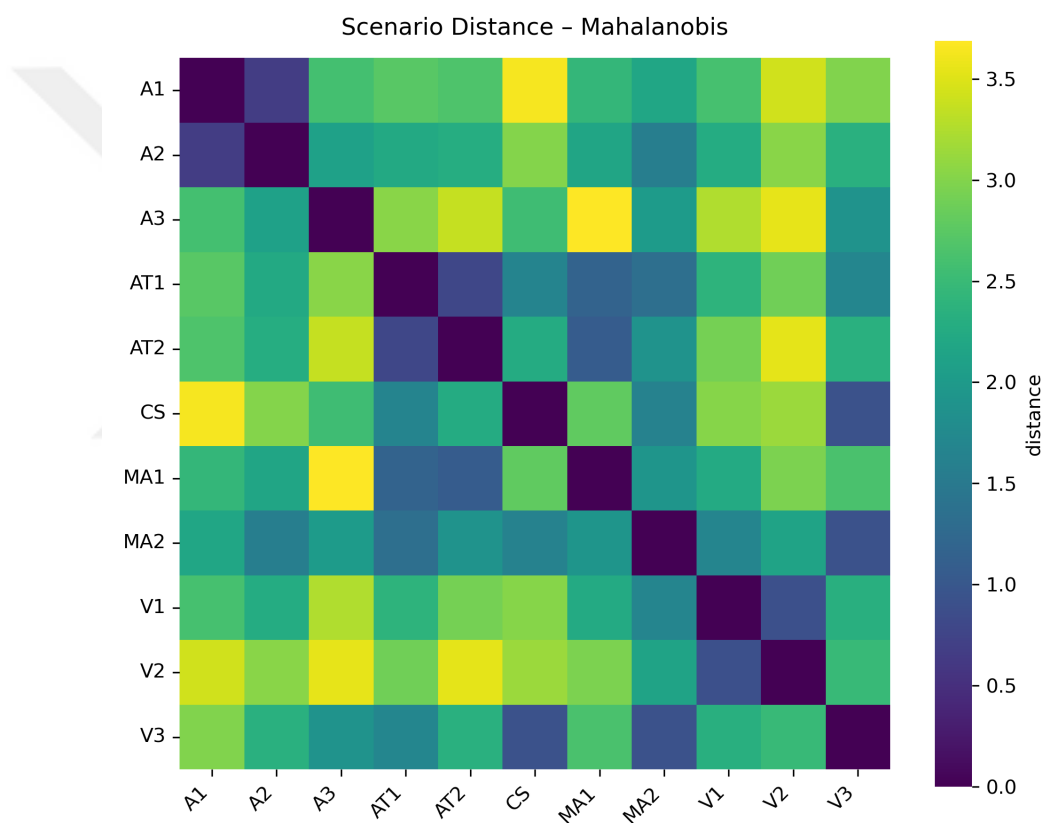


Figure D.2: Scenario-based heat map – Mahalanobis. In the heat-map legend, dark/navy blue cells indicate high similarity—that is, a small Mahalanobis distance, suggesting the two scenarios fall within the same cluster—whereas yellow cells mark low similarity, reflecting large distances and implying the scenarios belong to separate clusters.

Appendix E

Distance Matrices (Deaf Data)

Table E.1: *Euclidean Distances Among All 11 Scenarios*

	A1	A2	A3	AT1	AT2	CS	MA1	MA2	V1	V2	V3
A1	–										
A2	1.442	–									
A3	0.997	0.584	–								
AT1	0.380	1.103	0.677	–							
AT2	1.184	1.503	0.975	1.141	–						
CS	0.447	1.685	1.163	0.724	0.946	–					
MA1	0.413	1.309	0.774	0.451	0.774	0.390	–				
MA2	0.321	1.712	1.227	0.679	1.159	0.231	0.493	–			
V1	0.227	1.269	0.786	0.245	1.011	0.481	0.249	0.462	–		
V2	0.606	1.826	1.288	0.878	0.940	0.170	0.519	0.350	0.638	–	
V3	0.582	1.976	1.465	0.919	1.258	0.366	0.709	0.297	0.711	0.341	–

Note. Smaller values indicate greater similarity.

Table E.2: Mahalanobis Distances Among All 11 Scenarios

	A1	A2	A3	AT1	AT2	CS	MA1	MA2	V1	V2	V3
A1	–										
A2	2.741	–									
A3	2.334	2.584	–								
AT1	2.091	3.636	1.716	–							
AT2	3.686	4.053	2.653	3.803	–						
CS	1.480	2.963	2.838	3.199	2.981	–					
MA1	1.249	2.645	1.692	2.213	2.442	1.177	–				
MA2	1.099	2.950	3.032	3.106	3.630	0.719	1.480	–			
V1	0.952	2.877	1.558	1.320	3.152	1.888	0.988	1.835	–		
V2	1.670	3.342	2.699	3.019	2.562	0.639	1.044	1.206	1.790	–	
V3	1.667	4.108	2.561	1.833	3.318	2.159	1.676	2.155	1.307	1.791	–

Note. Smaller values indicate greater similarity. Values are rounded to three decimals.

Appendix F

Scenario Heat Maps (Deaf Data)

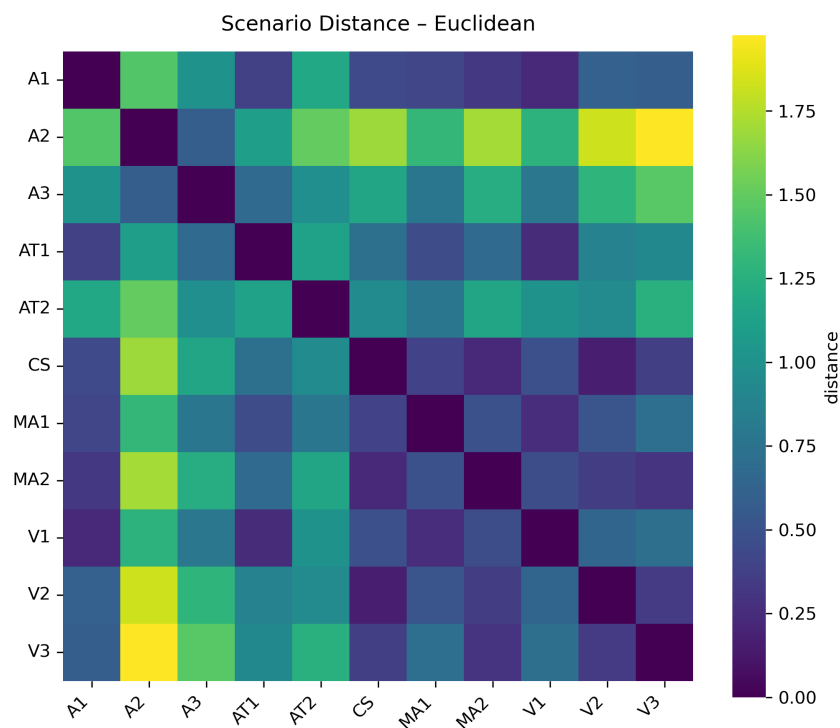


Figure F.1: Scenario-based heat map – Euclidean. In the heat-map legend, dark/navy blue cells indicate high similarity—that is, a small Euclidean distance, suggesting the two scenarios fall within the same cluster—whereas yellow cells mark low similarity, reflecting large distances and implying the scenarios belong to separate clusters.

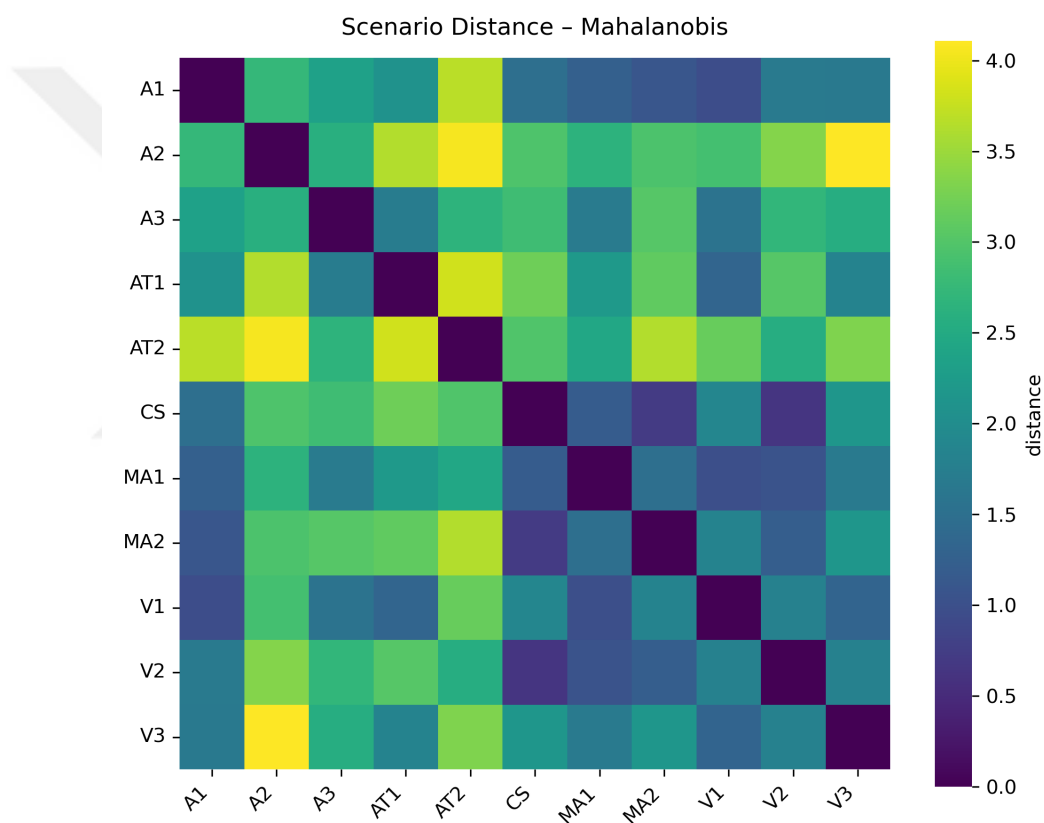


Figure F.2: Scenario-based heat map – Mahalanobis. In the heat-map legend, dark/navy blue cells indicate high similarity—that is, a small Mahalanobis distance, suggesting the two scenarios fall within the same cluster—whereas yellow cells mark low similarity, reflecting large distances and implying the scenarios belong to separate clusters.