The Faculty of Humanities
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Goal Recognition

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Abstract

The human capacity to recognize another agent's plans and goals allows it to infer missing and future actions and predict the agent's goal. This ability constitutes a fundamental aspect of human social cognition. An in-depth understanding of these cognitive processes serves to identify impairments and promote advanced research in psychology. Additionally, it is relevant to engineering and artificial intelligence, as it can contribute to the development of algorithms for the recognition of goals and plans by computers.

Contemporary algorithms for detecting agent intentions operate on the principle of rationality, assuming a predefined list of potential targets. To improve these algorithms to the level of human capacity that has dynamically formulated lists of goals, we need to understand the cognitive and visual attributes utilized by individuals in the goal-selection process. In this study, we propose that the Gestalt Laws serve as a foundational framework for comprehending visual perception's role in goal selection.

To test the aforementioned hypothesis, a visual experiment was conducted. Participants were tasked with determining the appropriate placement of an object in space while being surrounded by other objects characterized by Gestalt Law features.

We present the experiment's findings, revealing that Gestalt Law does indeed underlie the visual cognitive processes involved in goal selection. In addition, the data collected yields a wealth of information that can be leveraged for further research and exploration of unaddressed questions, such as potential priority distinctions between characteristics.

תקציר

היכולת האנושית לזהות תוכניות ומטרות של סוכן אחר מאפשרת לו להסיק מסקנות על פעולות חסרות ועתידיות ולחזות את מטרת הסוכן. יכולת זו מהווה היבט בסיסי של הקוגניציה החברתית האנושית. הבנה מעמיקה של תהליכים קוגניטיביים אלו משמשת לזיהוי ליקויים ולקידום מחקר מתקדם בפסיכולוגיה. בנוסף, תחום מחקר זה רלוונטי להנדסה ולבינה מלאכותית, מכיוון שהוא יכול לתרום לפיתוח אלגוריתמים לזיהוי מטרות ותוכניות על ידי מחשבים.

אלגוריתמים עכשוויים לזיהוי כוונות סוכן פועלים על עיקרון הרציונליות, מתוך הנחה הכוללת רשימה מוגדרת מראש של יעדים פוטנציאליים. כדי לשפר את האלגוריתמים הללו לרמת היכולת האנושית, שגיבשה באופן דינמי רשימות של יעדים, עלינו להבין את התכונות הקוגניטיביות והוויזואליות המשמשות אנשים בתהליך בחירת המטרה. במחקר זה, אנו מציעים כי חוקי הגשטאלט עשויים לשמש מסגרת יסוד להבנת תפקידה של התפיסה החזותית בבחירת מטרות.

כדי לבדוק את ההשערה האמורה, נערך ניסוי חזותי. על המשתתפים הוטלה המשימה לקבוע את המיקום המתאים של אובייקט במרחב, תוך שהם מוקפים באובייקטים אחרים המאופיינים בתכונות של חוק הגשטאלט.

אנו מציגים את ממצאי הניסוי ומגלים שחוק הגשטאלט אכן עומד בבסיס התהליכים הקוגניטיביים החזותיים הכרוכים בבחירת מטרות. בנוסף, הנתונים שנאספו מציגים שפע של מידע שניתן למנף אותו למחקרי המשך וחקירה של שאלות אותן לא חקרנו במחקר זה, כגון הבחנות עדיפות אפשריות בין מאפיינים.

1. Introduction

Goal recognition is a significant facet of human cognition, as it allows individuals to comprehend the intentions of others through the observation of their actions and behavior. The topic garners attention from multiple academic fields and methodologies, owning to its substantial theoretical and practical implications. Goal recognition assumes a vital role in domains like intelligent surveillance systems (Foo, Ng, Ng, & Yang, 2007), as well as in human-machine and human-robot interactions (Miró, Osswald, Patel, & Dissanayake, 2009), identification of terrorist activity (Jarvis, Lunt, & Myers,2005), inferring drivers' intentions (Salvucci, 2004), intelligent tutoring systems (Liu, Wang, Li & Zhao, 2011; Whitaker & Bonnell, 2009), simulations such as military simulation (Heinze, Goss, & Pearce, 1999), and entertainment such as in open world digital games (Min, Mott, Rowe, Liu, & Lester, 2016).

In Psychology, goal recognition is explored as a component of the *theory of mind*, which pertains to the ability of individuals (including some animals) to attribute mental characteristics, such as intentions, plans, and beliefs, to others, and utilize these mental attributes in their own decision-making processes. The theory of mind was first introduced by Premack & Woodruff (1978) and Baron-Cohen, Leslie, & Frith (1985). Meltzoff (2002) and Slaughter (2020) have provided evidence demonstrating that the development of theory of mind in humans occurs progressively during the ages 3-4. It has been shown to also develop (to a lesser extent) in chimpanzees and other primates (Premack & Woodruff, 1978).

The mechanisms underlying Theory of Mind have been investigated in neuroscience. Neuroscience elucidates "Theory of Mind" through the neural mechanism known as "mirror neurons" (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). This system comprises a network of neurons in the brain that is activated both when an individual performs a specific action and when they observe someone else performing the same action, effectively mirroring the observed action. Mirror neurons were initially discovered in monkeys through research conducted by Rizzolatti & Craighero (2004). The mirror neuron system is believed to play a significant role in the recognition of intentions and goals (Van Overwalle, & Baetens, 2009; Fogassi et al., 2005) beginning in childhood as the system develops (Lepage, & Théoret, 2007).

Various methods of brain imaging have been used to demonstrate the activation of the mirror system during both perception and generation of motor actions.

(Cochin, Barthelemy, Lejeune, Roux, & Martineau ,1998; Bekkering, Wohlschlager, & Gattis, (2000).

In the field of artificial intelligence (AI), goal recognition is a topic of investigation within the research area called Plan, Activity, and Intent Recognition (PAIR; Sukthankar, Geib, Bui, Pynadath, & Goldman, 2014). Typically, AI approaches goal recognition as an *inference* process.2 Given (1) observations of an agent's behavior (actions) within its environment, and (2) knowledge about its decision-making processes, goal recognition is viewed as the abductive process of inferring the goals or intentions of the observed agent.

There are two distinct families of approaches to goal recognition. The traditional *library-based recognition* approach encodes the knowledge of the observed agent's decision-making process in the form of a recognition *plan-library*. This library is then searched to identify matches for the observed actions (Kautz 1987; Charniak & Goldman 1993; Geib & Goldman, 2009; Avrahami-Zilberbrandt & Kaminka 2005). In more recent developments, the *rationality-based recognition* approach has gained prominence, notably pioneered by Ramirez and Geffner (2009, 2010). This approach uses a model-based planner to generate matching plans dynamically (Sohrabi, Riabov, & Udrea, 2016; Vered, Kaminka, & Biham, 2016; Vered & Kaminka, 2017; Kaminka, Vered, & Agmon, 2018; Masters & Sardina, 2017).

Both approaches assume the availability of a library (or list) of possible goals as part of the description of the decision-making process. For instance, when observing a pedestrian navigating city street, the first approach relies on a library of possible paths, while the new approach dynamically generates potential paths through aa path-planner. In both cases, the potential goal locations are assumed to be known.

Recently, several investigations have challenged the compatibility of these approaches with human cognition. Treger and Kaminka (2022) conducted experiments with human subjects, providing a comprehensive analysis that demonstrates that neither rationality-based nor plan-based recognition approaches can account for the results of the experiment.

In another experiment, Bonchek-Dokow and Kaminka (2014) found that human subjects generated hypothesized goals for recognition based on the observed behavior. Rather than starting with a predetermined list of potential goals and inferring their likelihood based on observed behavior, humans generated potential goals based on their observations.

Hence, a fundamental component of goal recognition is the *perception of potential goals amidst* all conceivable perceived goal states, while disregarding observed actions.

Which states hold a higher likelihood than others? This inquiry has been raised also within the realm of multi-agent coordination, employing game-theory *focal points* (Kraus, Rosenschein, & Fenster, 2000). The aforementioned work has delved into this question in broad terms, and we will focus on addressing it with more concrete visual perception notions.

Indeed, the question of favoring certain visual features is related to a field of research in machine vision, which focuses on *image saliency (see Niebur, 2007),* i.e., the features of an image to which humans attend earlier than others. However, it is important to note that while image saliency primarily deals with existing images, our investigation centers around human preference for (hypothesized) images. For instance, our focus is on where objects should be placed, rather than where they are currently located.

Consequently, we propose that the Gestalt laws, as were introduced in by German psychologist Kurt Koffka (1935) , can serve as a foundational framework for comprehending the perceptual element in goal recognition.

1.2 Gestalt Principles

1.2.1 General

Gestalt psychology attempts to elucidate a set of principles that delineate how humans perceive and organize visual information. It highlights the notion that the whole is greater than the sum of its parts, and that the human mind inherently arranges visual stimuli into meaningful patterns and structures. This conceptual framework was described by Köhler (1947) in "Gestalt psychology; an introduction to new concepts in modern psychology" as well as in "Gestalt Psychology: The Definitive Statement of Gestalt theory" by Kurt Koffka (1935). Gestalt psychology emphasizes the significance of holistic perception and the role of the context in shaping our perceptions.

Gestalt perception principles (Gestalt laws of grouping) facilitate comprehension of how the human visual system organizes and interprets visual stimuli. Through the study of these principles, researchers from diverse disciplines can gain insights into creating and enhancing communication (Sinitskaya, 2019), understand the visual stimulus processing in newborns (Farroni, Valenza, Simion, & Umilta, 2000), understanding human image perception (Biederman, 1987), improving visual communication, comprehending brain visual processes (Gerard-Mercier, F., Carelli, P. V., Pananceau, Troncoso, & Frégnac, 2016); Sigman, Cecchi, Gilbert, & Magnasco, 2001), and enriching artificial applications such improving deep convolutional networks (Amanatiadis, Kaburlasos, & Kosmatopoulos, 2018). Understanding deep convolutional networks through Gestalt theory, or use it in the image processing (Wörgötter et al., 2004). However, none of the studies above handles the world of goal recognition. In this study, our investigation centers around examining the impact of Gestalt principles on the *perceptual* element in goal recognition.

1.2.2. Gestalt Principles as a Basis for Goal Recognition

The initial step involves identifying the relevant parts and principles withing the Gestalt framework that pertain to goal recognition. We suggest a subset of Gestalt principles as key elements for comprehending the cognitive model:

1. Proximity: Elements in proximity are perceived as a group or single entity.

2. Similarity：Elements sharing similar attributes, such as shape, size, or color, are perceived as belonging to the same group.
3. Closure：Our tendency to mentally complete incomplete or fragmented visual information, perceiving it as a meaningful whole.
4. Continuity：Our inclination to perceive visual elements in a smooth and continuous manner.
5. Symmetry：Symmetry suggests that we perceive objects as more stable, harmonious, and aesthetically pleasing when they exhibit symmetry or balanced proportions.

These principles of Proximity, Similarity, Closure, Continuity and Symmetry are particularly relevant to goal recognition, as they aid in identifying behavioral patterns and relationships that may indicate an agent's preferred goals. For instance, the principle of proximity suggests that objects in proximity are likely to be perceived as belonging to the same group, enabling us to infer that closer goals may be preferable.

To initiate the investigation of the relationship between goal recognition and Gestalt principles, we simplified the context to a two-dimensional world. Subsequent stages of research (not covered in this work) aim to conclude the findings to real-world scenarios.

2.Human Goal Recognition in 2-dimensional visual world

Our proposed approach for understanding the cognitive model of goal recognition centers around the utilization of Gestalt laws. This chapter provides a comprehensive exploration of each Gestalt principle and its relevance in the context of goal recognition, specifically in the generation of possible goal hypotheses. These principles were developed within the context of image perception, i.e., as perceptual rules for finding patterns and simplifying image understanding. Thus, our emphasis lies in leveraging these principles for goal recognition within the realm of two-dimensional (2D) visual perception, particularly in the identification of potential goals in images that describe object positions and their interrelationships.

The first section of this chapter introduces the task of goal recognition in 2D images (Section 3.1). Subsequently, we delve into the application of Gestalt principles to the process of hypothesizing goals within images (Section 3.2).

2.1 Cognitive characteristics for goal recognition in the 2-dimensional visual world

To hypothesize goals in the 2D images, researchers make educated guesses or predictions about the intentions or objectives depicted within the image. The process involves analyzing the visual content and context to infer the potential aims or purposes of the subjects or elements presented in the image.

When formulating hypotheses about goals in a 2D image, we rely on understanding of the subject matter, human behavior, and the visual cues provided within the image. This analysis may involve examining the relationships between objects, evaluating the environmental context, and considering any other relevant detail that may contribute to the understanding of the depicted goals.

For instance, let's consider a specific scenario depicted in an image. In this image, two non-close objects are present, and their arrangement suggests the possibility of combining them into a circle, as exemplified in Figure 1. Based on this visual observation, we can make prediction about the goal portrayed in the image: the intention is likely to involve moving one of the objects toward the other in a manner that allows both objects to move into a circle.

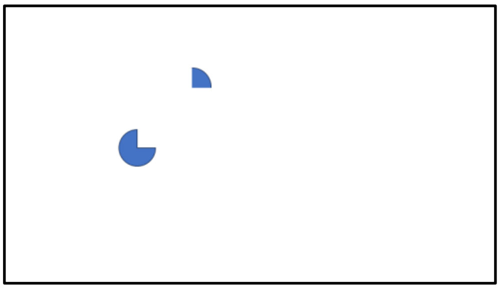


Figure 1 - 1 example of visual cue for goal recognition in the 2D image

2.2 Applying Gestalt principles of perception to Goal Recognition in 2D images

Our focus lies on exploring the application of Gestalt principles of perception to the process of goal recognition in 2D images. Specifically, we delve into the following Gestalt principles: Similarity, proximity, Symmetry, Closure, and Continuation. In this work, each characteristic is examined individually as a distinct property, while also acknowledging the importance of exploring the relationships, conflicts, and priorities between these characteristics.

2.2.1. Similarity - shared visual characteristics

Similarity is a complex characteristic that combines sub-characteristics in the similarity world. In the context of the 2D world, similarity is when items share visual characteristics. In this scenario, they are perceived as more related than objects that are dissimilar.

This study primarily examines three key visual characteristics: colors, shapes, and sizes, which are defined as follows:

- COLOR: This refers to the color of the target objects. The underlying assumption is that when individuals need to move an object within a 2-dimensional surface towards a goal, they are more likely to select an object whose color is identical to the moving object.
- SHAPE: This pertains to the shape of the target objects. The assumption in this case is that individuals tend to prefer a target object that possesses the exact same shape as the moving object.
- SIZE: This characteristic relates to the size of the target objects. Similarly to color and shape, the assumption is that individuals are inclined to choose an object with the same size as the moving object.

An example illustrating the application of similarity in the sub-characteristics of color, shape, and size can be observed in Figure 2, where two objects exhibit similarity in color and shape but differ in size.

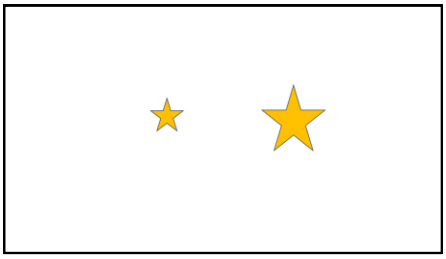


Figure 2 - Shape and Color Similarity

Similarly, in Figure 3, the two objects share similarity in shape and size but differ in color.

Figure 3 - Shape and Size Similarity

It is crucial to explore each of these sub-characteristics individually, as well as investigate the prioritization and conflicts that may arise between them. A Conflict between the sub-properties occurs when the target objects have different similarity subsets and the question which one of the objects will be the target object. When conflicts occur among the sub-properties, several possible resolutions can be considered:

- There is a list of priorities between them, and the chosen one is the one with the highest priority.
- An object is chosen randomly among the conflicting options.
- No object will be chosen.

An example of a conflict between sub-properties can be observed in Figure 4, where two objects at the top of the picture exhibit different similarity properties compared to the third object at the bottom - one shares the same shape, while the other shares the same color.

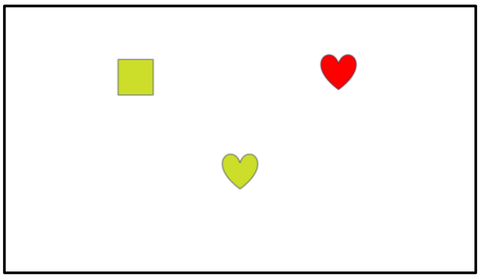


Figure 4 - Similarity Color-Size conflict

It is important to note that this work does not explore certain properties that are typically considered as part of similarity, such as texture and complex objects that are composed of multiple simple objects.

2.2.2. Proximity as a relatedness between objects

Proximity serves as one of the simplest characteristics, referring to the distance or closeness between two objects. We aim to examine how distance influences the decision-making process in goal recognition within the 2-dimensional visual world. Our hypothesis posits that objects in proximity appear more related compared to objects that are further apart. Therefore, we assume that humans are more likely to target objects that are closer to each other rather than those that are more distanced.

However, there is a crucial consideration when exploring the effect of distance on goal recognition. While distance is a straightforward property, it always operates in the background of other properties. When analyzing other characteristics, the distance between an object and the entire set of potential goal objects is always present. Consequently, it becomes essential to carefully remove any potential noise originating from the distance characteristic when investigating other properties.

An example of the different distances can be seen in Figure 5. The circle object at the bottom of the picture has a small distance from one of the rectangle objects but larger distances from the other rectangle objects.

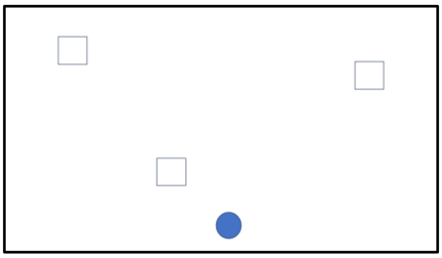


Figure 5 - example for different Proximity

2.2.3. Symmetry - visual balancing

The symmetry characteristic describes the concept of visual balancing within the 2-dimensional world. In the context of goal recognition, our theory suggests that humans tend to choose one goal over another if it provides visual balance.

Several parameters of visual balancing need to be considered during the exploration:

- Position: When looking for Symmetry in the 2-dimensional world, position refers to the location of the axis that creates the symmetry. For instance, symmetry around the X-axis at the center or symmetry around the Y-axis located right to the center. We can go further and use different axes located all over the surface. It is crucial to explore different positions.

- Level of Symmetry: This parameter represents the degree of symmetry achieved. Full visual balance involves selecting three axes (X, Y, and the 45-degree axis between X and Y) that intersect at the center and result in complete symmetry between the two parts created by the axis on the surface. In contrast, partial symmetry at various levels can be achieved, such as symmetry only with the X-axis at the center or symmetry only with the Y-axis away from the center. As in the previous parameter, different levels of symmetry should be explored.

- Different Options to Symmetry: When moving an object towards a specific target in the realm of symmetry, multiple options may exist to create symmetry with the moving object. Understanding the various options and determining if a specific option is preferred over others, along with the underlying reasons, is crucial. The position and level of symmetry can influence decision-making in such cases.

Figure 6 illustrates the same set of objects that creates full symmetry but positioned differently.

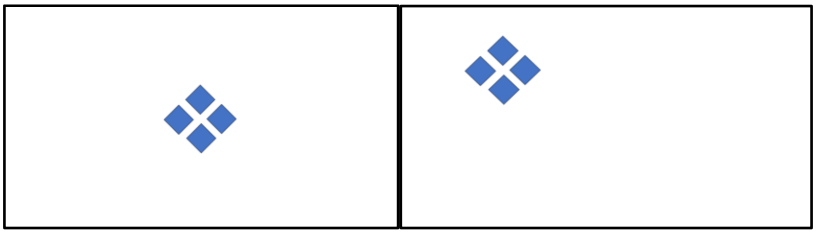


Figure 6 - Full Symmetry, different positions

Figure 7 demonstrates objects that exhibit full symmetry, while Figure 8 depicts an object creating partial symmetry with the Y-axis.

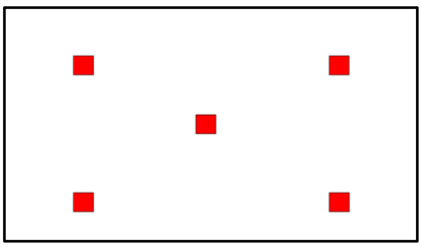


Figure 7 - Full Symmetry

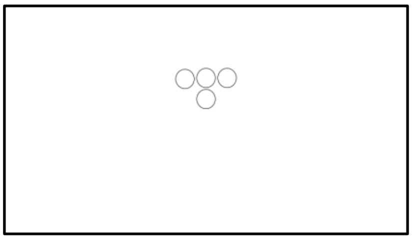


Figure 8 – Partial Symmetry around Y axis

2.2.4. Closure - Complete visual object/pattern

Closure in the 2-dimensional world and objects refers to the human inclination to mentally close up or complete objects that are not complete. In the context of this study and goal recognition, the hypothesis is that humans exhibit a preference for one object as a goal over another if it allows for the visual closure of a known pattern or shape.

There are two primary cases of closure in the 2-dimensional world objects:
1. Well-known patterns: This case involves a familiar pattern, such as a circle, that may have a missing part. Closure in this context entails mentally completing the missing portion to perceive the pattern as complete and whole.

2. Shapes without fully continuous properties: In this scenario, the shape lacks overall continuity or visual harmony, such as missing symmetry or similarity. Closure, in such cases, involves mentally closing the gaps and bringing the shape closer to a state of harmony or completion.

Our hypothesis posits that the presence of closure in a potential goal influences the decision-making process, leading humans to prefer goals that exhibit closure.

The first case is illustrated in Figure 9, where two objects can form a triangular shape.

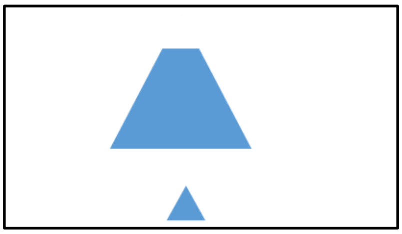


Figure 9 - Closure - known shape

The second case can be seen in Figure 10, where one object has a missing part that can be fulfilled by the other object.

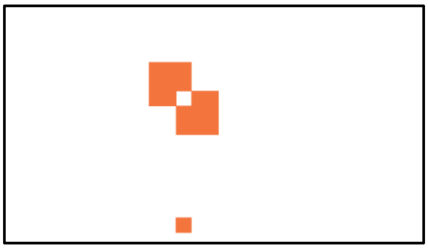


Figure 10 – Closure - fulfill missing part

2.2.5. Continuation - following continuous movement

Continuation refers to the tracking of an object's movement from one position to another on a two-dimensional surface. The movement itself can be categorized into three groups:

1. Static movement: This type of movement involves continuous motion without any changes, such as linear movement.
2. Patterned movement: It encompasses movement with a repeated pattern, like that of a sinusoidal graph.
3. Random movement: This type of movement can change at any time and occur at any position.

Figure 11 illustrates two types of movement, linear and patterned, represented by lines.

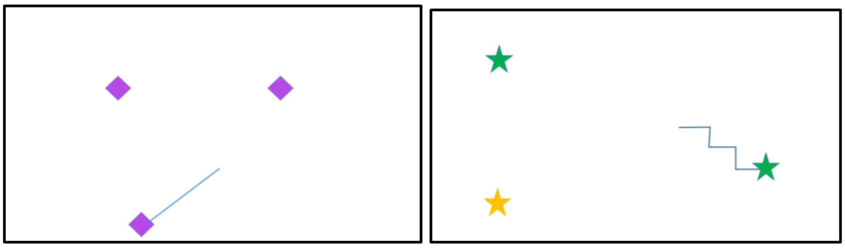
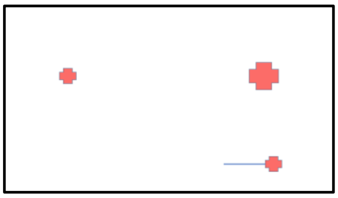


Figure 11 - Continuation different movements – linear in the left and patterned in the right

In addition to movement types, the length of the movement and the presence of objects in the movement track are also important factors to consider. Figure 12 depicts different movement lengths, marked by lines, including both short and longer movements.



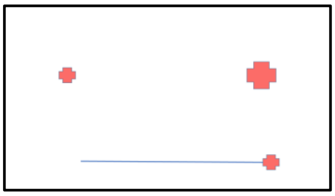


Figure 12 - Continuation different movement lengths

Our assumption is that continuation affects the decision-making process in goal targeting, leading humans to prefer goals that appear along the path of movement over those that are not. If such case, with the first two groups, it is relatively easier to anticipate potential goals. However, with random movement, it becomes more complicated as humans cannot extrapolate the potential end positions and, consequently, the goals.

2.2.6 Conflicts and characteristics' priorities

In our discussion, we have described a set of characteristics and their potential impact on goal recognition in humans. These characteristics were described in isolation, without any external noises or conflicts with each other. However, it is essential to explore the effect of conflicts between these characteristics on goal recognition.

An additional aspect to be investigated is the priority order between these characteristics. The main objective is to determine if there is a specific order or hierarchy among them. Section 6.6 provides details on how this aspect was addressed in the experiment. It is important to note that the analysis of conflict results is not included in this work and will be explored separately.

3. A Web-Based Experiment

To examine the hypothesis suggesting the utilization of Gestalt principles of perception in human cognition to propose potential goals, we devised a web-based experiment. 910 participants were presented with 2D environments and asked to report their preferences regarding the placement and arrangement of objects.

The rationale and requirements for conducting this experiment are described in Section 4.1, followed by a detailed discussion of the experiment design in Section 4.2. The data collection and curation processes are subsequently addressed in Section 4.3.

3.1 Rationale and Overview

In order to validate the suggested characteristics and their interrelationships, a suitable platform was sought to conduct the experiments with the following required capabilities:

- Automatic execution of experiments without human intervention.
- Unlimited number of executions.
- No restrictions on execution dates.
- Ability to update the experiment.
- Access to a large, relevant, and diverse audience.
- Provision for archiving results.
- Automatic execution of results analysis.

3.2. The Amazon Mechanical Turk platform

After careful consideration, the Amazon Mechanical Turk platform was selected as it fulfills these requirements. This platform is widely used, user-friendly, and highly valuable for research purposes, as discussed by Farrell & Sweeney (2021). To maximize the success of the crowd-sourcing experiments conducted on the AMT platform, it is recommended to follow several best practices and recommendations, as outlined Aguinis, Villamor, and Ramani (2021). These guidelines aim to align the system's methods and terms with the goals of the experiment.

3.3. General Overview of the experiment

In our study, a series of offline experiments were prepared and uploaded to the Mechanical Turk platform for execution. Each experiment was conducted by one experimenter, and the results were stored in permanent storage for further analysis. The experimenter received compensation based on their performance: full compensation plus a bonus for executing each part of the experiment, full compensation if the experimenter completed the experiment but not all parts, and no compensation if the experimenter exited the experiment prematurely.

The basic framework of each experiment remained consistent, wherein each experimenter performed 20 different tasks. Each task examined a specific case of one of the characteristics under investigation. Tasks consisted of several static objects and one dynamic object. For each task, the experimenter was given 30 seconds to decide the desired placement of the dynamic object on the screen. The experiment ended either when all 20 tasks were reviewed and answered or if the experimenter chose to exit the experiment before completion.

The experimenter proceeds through six steps to complete the experiment:

1. First step: The experimenter receives a clear description of the experiment and instructions on what is expected from them. Information regarding payment and potential bonuses is also provided.
2. Second step: The experimenter is presented with a visual demo that visually reinforces the instructions received in the first step.
3. Third step: The experimenter is required to answer four questions to confirm their understanding of the instructions. If any question is answered incorrectly, the experimenter must repeat the question.
4. Fourth step: The experimenter submits personal data, including age, gender, and dominant hand, which will be used for results analysis.
5. Fifth step: This is the core phase of the experiment. The experimenter is presented with 20 pictures sequentially. Each picture contains several static objects and one dynamic object, which is the only object that can and must be moved. The dynamic object flashes for the first 5 seconds. After that, the experimenter has 30 seconds to decide where to move the dynamic object based on the objects that appear in the picture and their locations. At this stage, the experimenter has three options: 1) Move the dynamic object and wait for 30 seconds until the system automatically proceeds to the next picture. 2) Move the dynamic object and request the system to move to the next picture. 3) Do not move the dynamic object and wait for 30 seconds until the system moves to the next picture. At any point during the experiment, the experimenter is provided with a countdown indicating the remaining time for the current task. Additionally, a progress bar indicates the overall progress of the experiment.
6. Sixth step: The experimenter is notified that the experiment is completed and has the option to provide feedback.

At any point during the experiment, the experimenter can choose to exit. However, if they do so, they will not receive payment, although their relevant data will still be stored.

After each experiment, three actions are undertaken:

1. Payment is automatically processed by the Mechanical Turk platform for experimenters who have completed the entire experiment.
2. Results are stored using the Firebase application. The stored data includes the experimenter's profile and, for each task, the movement made and the final position of the dynamic object. The stored data for experimenters who have not completed the entire experiment includes only the experimenter's profile.
3. Experimenters who have moved the dynamic object in every task receive a bonus. The bonus is awarded once every week time period for all experimenters who have completed the experiment since the last bonus distribution.

3.4. Experiment Design

Subject Selection

To ensure the success and reliability of the experiment, certain principles and limitations were incorporated into the design:

1. Experienced participants: The experiment was conducted with participants who met the following criteria:
   - Only participants with prior experience on Mechanical Turk were allowed to execute the experiment.
   - Participants needed to demonstrate understanding of the experiment's instructions.
   - Only individuals above 18 years old from the United States were eligible to participate.
2. Experiment duration: The experiment was designed to be completed within 10 minutes to maintain participants' focus and obtain optimal results. Therefore, it consisted of only 20 tasks.
3. Experiment coverage:
   - Each experiment included at least one task related to each of the characteristics being tested.
   - The tasks had an equal probability of appearing in any trial.
4. Experiment payment: To encourage participants to answer all questions, a bonus was added to the experiment's payment. However, if a participant exited the experiment before completion, no payment would be given.
5. Experimenter limitation: Each experimenter could participate in only one experiment to prevent potential bias from prior knowledge in subsequent rounds.

6. Experiment results:
   - Results were stored in a permanent storage system for further analysis.
   - Filtering of results could be easily done by experimenters or by specific questions.
7. Number of experiments: To ensure reliable results, a sufficient number of experiments 870, were conducted, providing at least 28 results for each task and 670 results for each characteristic explored.

3.5. Controlled conditions related to Gestalt

3.5.1. Similarity

To investigate the similarity property, a set of pictures was created for each sub-property. Additionally, it was necessary to examine conflicts and priorities among the sub-properties.

When exploring the **color**, **shape**, and **size** sub-properties, all the characteristics other the one being tested (color/shape/size) should be identical, to neutralize potential noise. In addition, three principles guided the construction of the relevant part of the experiment:

- The color/shape/size of the dynamic object should match one of the static objects but differ from the others.
- Various starting positions for the dynamic object were tested.
- To avoid bias, different locations, colors, sizes, and shapes were chosen for the static objects in different pictures.

Figure 13 demonstrates the implementation of these principles for the color testing (the dynamic object is pointed by an arrow). Each example uses different shapes, colors, and sizes. The illustrations showcase different shapes, colors, and sizes. However, within each example, all objects share the same shape and size, but exhibit varying colors.

Figure13 – Similarity, different Colors, Sizes and Shapes

Figure 14 illustrates the implementation of these principles for the shape and size testing. As in the figure above, the dynamic object is indicated by an arrow. Each figure presents different colors, sizes, and shapes. However, within each one of the first two figures, the objects share the same color and size, but the shape is different. In the last two figures, the objects share the same shape and color, but have different sizes.

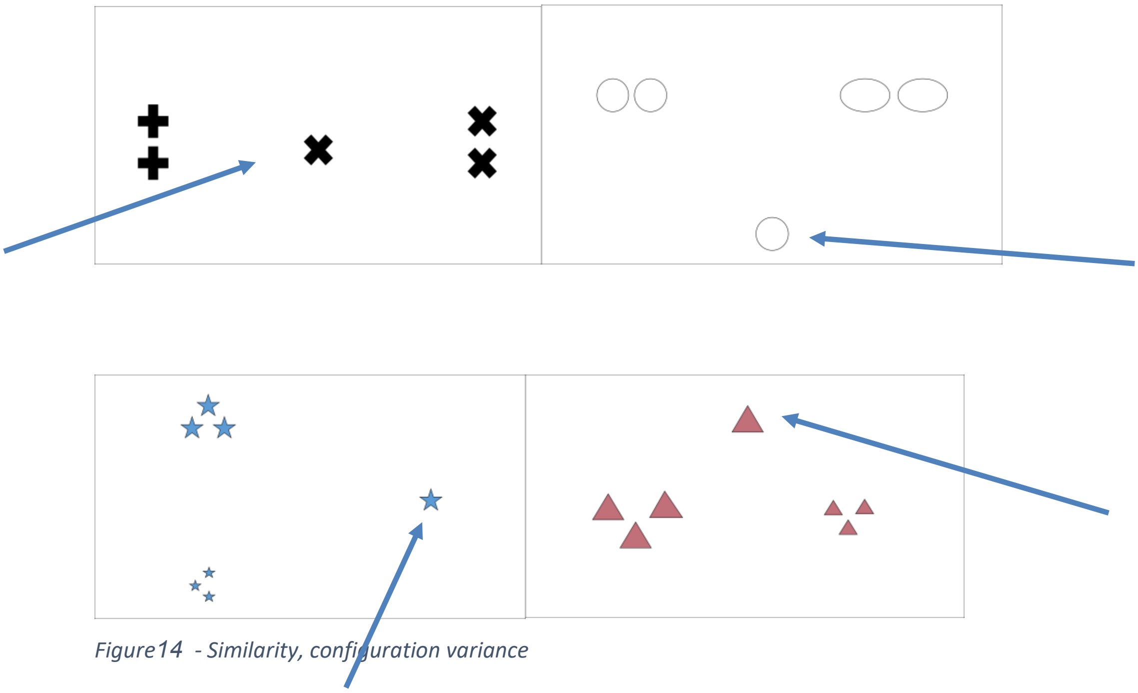


Figure 14 - Similarity, configuration variance

In addition to exploring the individual aspects of size, color, and shape in the experiment, we also examined cases involving conflicts between these characteristics to determine their priority.

Two types of patterns were tested:

The first pattern investigated the priority between two sub-characteristics, X and Y. The method that was used to test it is by two static objects that are different only in their X and Y values and the dynamic object value are: X as first object and Y as the second object and all other sub-properties are the same as with the static objects. This principle is reflected in table 1:

Sub-characteristic	Static object A	Static object B	Dynamic object

X	x.a	x.b	x.a
Y	y.a	y.b	y.b
Z	Z	Z	Z

Table 1 - Similarity, sub-characteristics' first type conflict

Similarly to previous cases, different start positions of the dynamic object should be tested. Additionally, to mitigate bias, various locations, colors, sizes, and shapes were selected for the static objects across different pictures.

Figure 15 illustrates the application of these principles for the shape-size conflict. The dynamic object in the figure shares the same color and shape as the first group of static group but differs in size. It also shares the same color and size as the second static group but differs in shape.

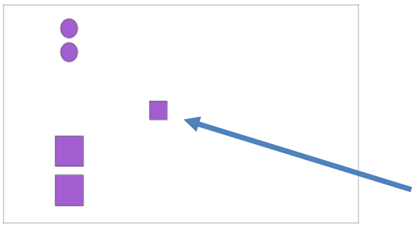


Figure 15 - Similarity, shape-size conflict

The shape-color conflict is presented in the figure 16. The dynamic object has the same color and size as the static group at the left but has different shape and has the same shape and size as the right static group but has different color.

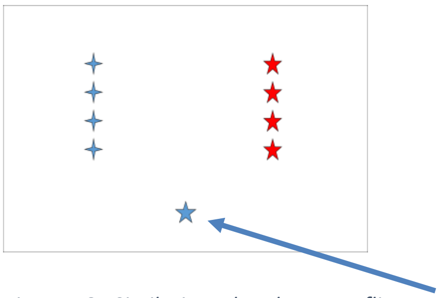


Figure 16 - Similarity color-shape conflict

The second pattern examined the effect of the number of identical sub-characteristics. The method that was used to test it is by two static objects that have different numbers of sub-characteristics which are identical to the dynamic object. This principle is reflected in table 2:

Sub-characteristic	Static object A	Static object B	Dynamic object
X	x.a	x.b	x.b
Y	y.a	y.b	y.a
Z	z.a	z.b	z.a

Table 2 - Similarity, sub-characteristics' second type conflict

In this pattern, a dynamic object is identical to static object A with Y, Z (two sub-characteristics) but to object B only with Z (one sub-characteristic). There are different combinations for this pattern such as size and color vs shape, but in our experiment, we specifically tested the conflict between size and shape versus size. A sample of this conflict can be observed in Figure 17 where the dynamic object has one identical sub-characteristic to the left static object - size and two sub-characteristics to the right static object - shape and size.

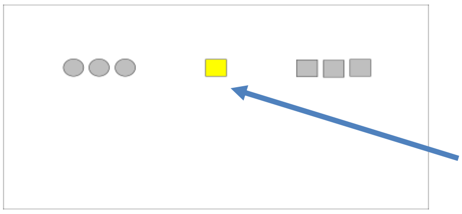


Figure 17 - Similarity Shape&Size vs. Size conflict

3.5.2. Proximity (Distance)

As mentioned earlier, proximity is an intricate characteristic as it underlies every other characteristic we examine. To address proximity in the experiment, the main principle employed was to isolate it from the other characteristics. In this approach, all static objects and the dynamic object are identical objects. They can be grouped together or appear as a

single object. The key aspect is that they are located in different positions, with at least one object having a different distance from the dynamic object compared to the others.
The pictures were divided into eight variants, which are described in detail in Table 3. The table provides an overview of the object sets for each variant.

Variant number	Number of static groups	Number of objects in each static group	Number of groups with minimal distance to the dynamic object	Comment
1	2	2-4	1	
2	3	3	1	
3	4	1	1	
4	2	2-3	2	All groups have the same distance from the dynamic object
5	4	1	4	All groups have the same distance from the dynamic object
6	4	1	2	2 groups with minimal distance, 2 with larger
7	4	1	3	3 groups with minimal distance, 1 larger
8	1	3-4	N/A	There are different distances to the different objects in the single static group

Table 3 - Proximity variants

Variants 1, 2, and 3 are highly similar, differing primarily in the number of static groups and the number of objects within each group. However, in all these variants, there is only one group that has the minimum distance to the dynamic object. Figure 18 provides samples of these variants.

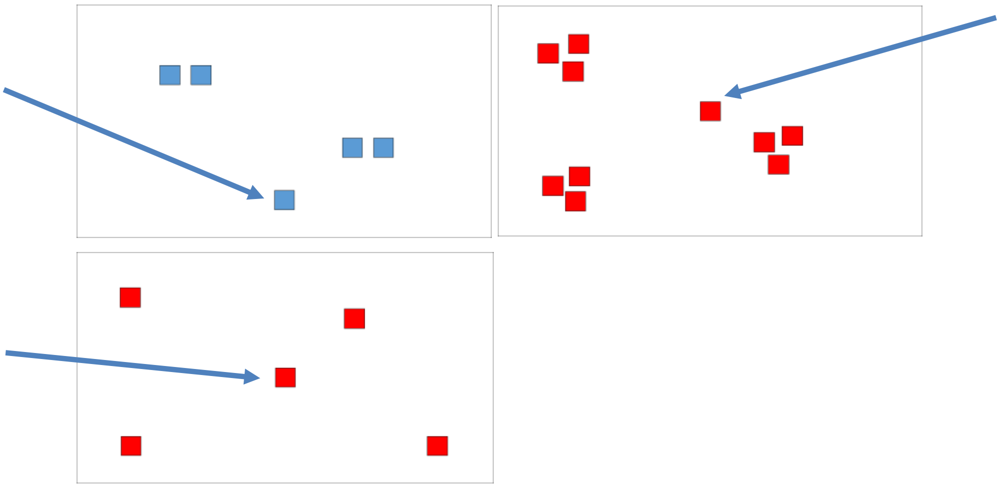


Figure18 - Proximity variants 1,2 and 3 examples

The next two similar variants, 4 and 5, feature multiple groups with the same distance from the dynamic object. The main distinctions between these two variants are the number of objects within the groups and the number of static groups. Figure 19 presents samples of these variants.

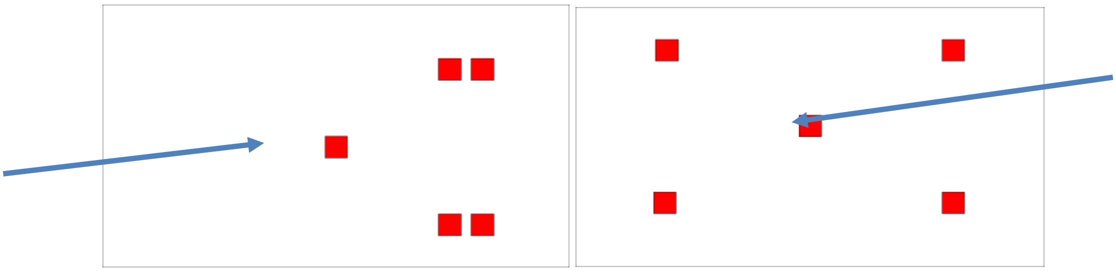


Figure19 - Proximity variants 4 and 5 examples

Moving to the following two similar variants, 6 and 7. Both consist of four static objects, more than one object has the smallest distance to the dynamic object, while at least one object that has a larger distance.
Samples of these variants can be seen in figure 20.

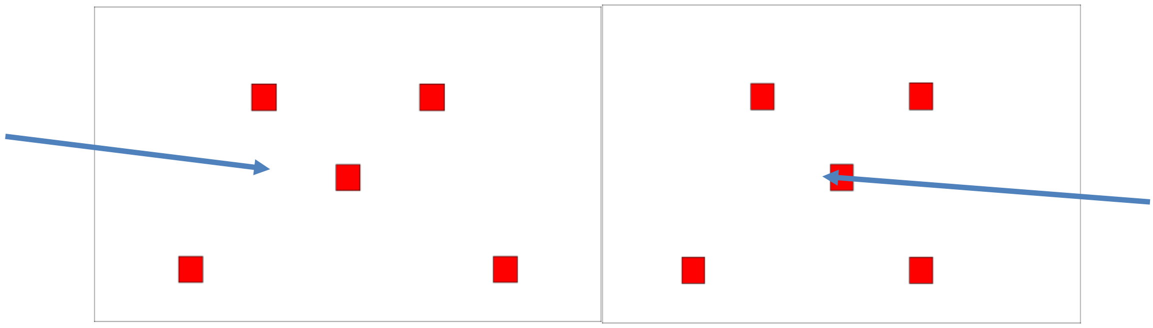


Figure 20 - Proximity variants 6 and 7 examples

The final variant, number 8, represents a scenario where we have a single group of objects. In this case, the dynamic object has different distances to each member of the group. Figure 21 showcases samples of this variant.

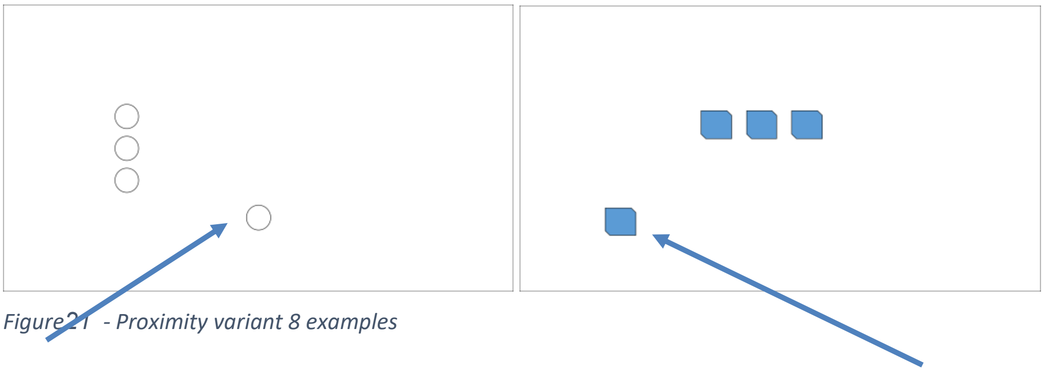


Figure 21 - Proximity variant 8 examples

3.5.3. Symmetry

The Symmetry characteristic encompasses several parameters, as outlined in section 3.2.3, including Position, Level of symmetry, and the chosen symmetry option in case multiple options exist. Seven different variants were created to cover different parameter values.

The commonality between the variants is that we have: Initial symmetry state and final symmetry state. Each state (Initial or Final) can be one of the following:

1. No symmetry: The static objects in the picture do not create any symmetry.
2. Full symmetry: The static objects in the picture create symmetry around all axes. Figure 22 illustrates an example of full symmetry.

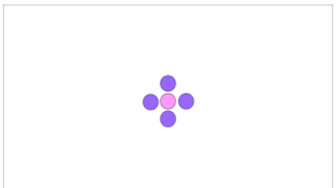


Figure 22 - Full Symmetry

3. Partial symmetry: The static objects in the pictures create symmetry as in the previous case (Full symmetry), but not with all axes. Figure 23 showcases an example of symmetry around the X axis.

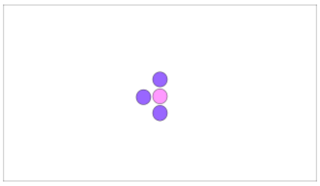


Figure 23 - Partial Symmetry

4. Semi/semi-partial symmetry: There are two or more parts of the static objects in the picture. At least one part exhibits internal symmetry, but when combined, they do not create any overall symmetry. In figure 24 we can see semi partial symmetry in the left side of the picture and only around the Y axis

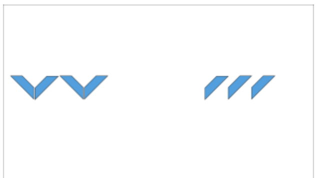


Figure 24 - Semi partial Symmetry

The table below describes the different variants that were tested, with the final state indicating the available options to achieve one of the symmetry types.

Variant number	Initial state (w/out object)	Final state			
		Full symmetry	Partial Symmetry	Semi partial symmetry	No symmetry
1	Full symmetry	Yes	Yes	No	Yes
2	Partial Symmetry	No	Yes	No	Yes
3	Partial Symmetry	Yes	Yes	No	Yes
4	No symmetry	Yes	Yes	No	Yes
5	No symmetry	No	No	Yes	Yes
6	No symmetry	No	Yes	No	Yes
7	Partial symmetry	No	No	No	Yes

Table 4 - Symmetry different variants

There are more options for combinations of the initial and Final state, but these 7 groups cover a major part of the functionality.

In the following section, we will review each group individually.

Group 1:
The initial state of the first group is fully symmetrical, which means that the static objects create full symmetry. The decision regarding the placement of the dynamic object can create full symmetry, partial symmetry (around Y axis or around 45 degree between X and Y axes) or no symmetry. Figure 25 provides samples from this group. As presented in this example and the next ones, the position of the symmetry differs between the examples, with the second sample showcasing symmetry in the center while the first sample does not have a centered symmetry.

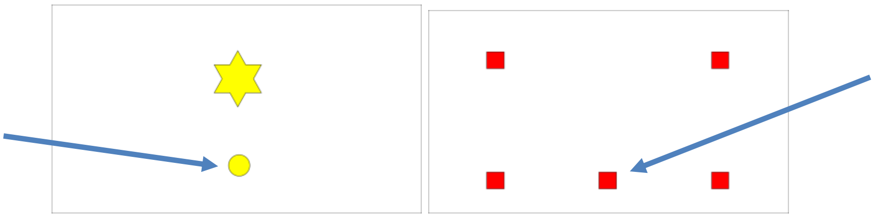


Figure 25 - Symmetry first variant examples

Group 2:
In the second group, the initial state is partial symmetry around the Y axis or between X,Y axes with 45 degrees. The dynamic object can create partial symmetry (in some cases around one axis and in other cases around more than one axis) or no symmetry.
Figure 26 showcases samples from this group.

Figure 26 - Symmetry second variant examples

Group 3:
In the third group, the initial state is partial symmetry around the Y axis or between X, Y axes with a 45-degree angle. The dynamic object can create full symmetry, partial symmetry (in some cases around one axis or around more than one axis) or no symmetry. Samples from this group are presented in figure 27.

Figure27 - Symmetry third variant examples

Group 4:

In the fourth group, the initial state does not exhibit any symmetry. However, by placing the dynamic object, the experimenter can create full symmetry, partial symmetry, or no symmetry. Figure 28 presents samples from this group.

Figure 28 - Symmetry fourth variant examples

Group 5:

The fifth group exhibits a unique scenario, in which there is no symmetry in the initial state, nor an option for full symmetry or partial symmetry. However, there is an option to create partial symmetry with one of the groups. As can see in figure 29 with the left group.

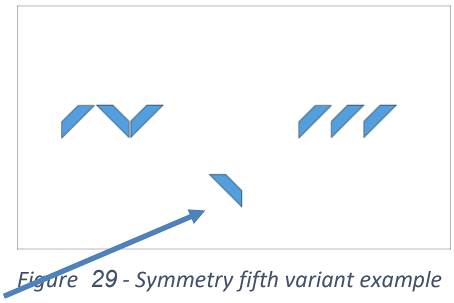


Figure 29 - Symmetry fifth variant example

Group 6:

In the sixth group, the initial state does not exhibit any symmetry, and the final state can only achieve partial symmetry. Figure 30 presents samples from this group.

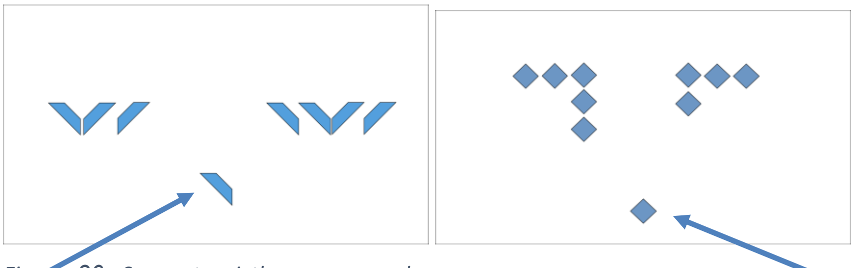


Figure 30 - Symmetry sixth group examples

Group 7:

The seventh group involves an initial state of partial symmetry. However, there are no options available to create symmetry with the dynamic options. A sample for that can be seen in figure 31.

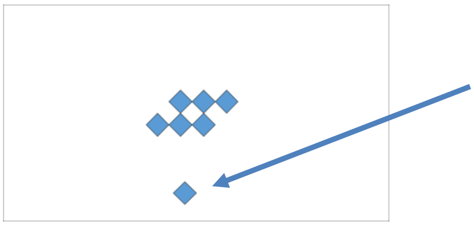


Figure 31 - Symmetry seventh group example

This case is considered less interesting as there is no element of symmetry in the final state. Any case the results show that there were different places where the dynamic object moved but none created symmetry.

3.5.4. Closure

To explore the Closure characteristic, four approaches were employed:

1. In the first approach, a picture with one static object that is a standard shape (e.g. circle) and part of it was removed. The dynamic object is identical to the part that was removed. Example is presented in figure 32.

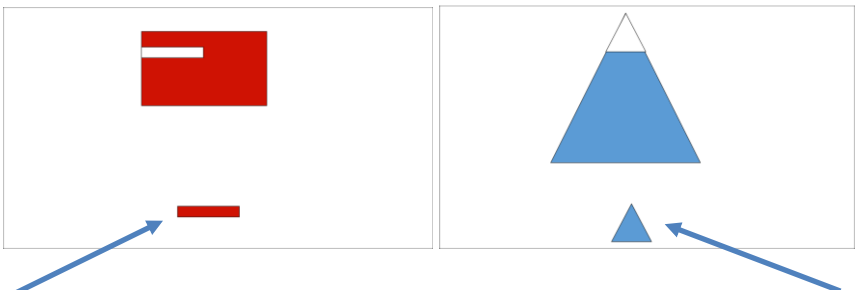


Figure 32 - Closure standard shape examples

2. The second option involves a static object with a missing part, resulting in a discontinuity in the object. The dynamic object can perfectly fill into the missing part, and as can see in the examples in figure 33

Figure 33 - Closure missing part examples

3. The third option is similar to the second one, but with more than one missing part on the static object. Figure 34 illustrates this option.

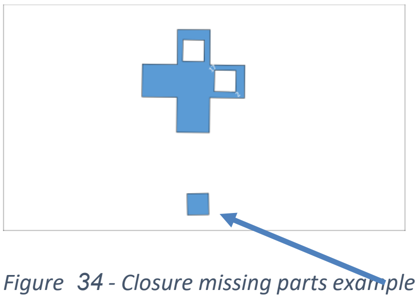


Figure 34 - Closure missing parts example

4. The last option incorporates a static object with more than one missing part, but the missing parts are not identical. The dynamic object is identical to a subgroup of the missing parts but differs from the others. Figure 35 provides two examples for this case.

Figure 35 - Closure different missing parts examples

3.5.5. Continuation

In this part of the experiment, the three types of movement mentioned earlier (static movement, patterned movement, and random movement) take center stage. Each picture consists of two identical static objects/groups and a dynamic object that is either identical or creates closureness (an object that can create closure). For each picture, the dynamic object follows one of the movement types as a track during the initial few seconds.

An example of the first type of movement, static movement, is depicted in Figure 36. The line illustrates the movement trajectory of the dynamic object during the initial seconds.

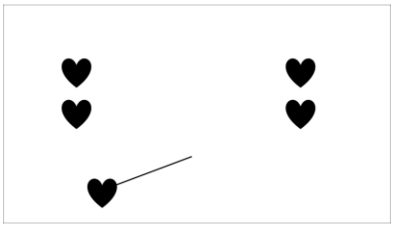


Figure 36 - Continuation example

Additional examples of static movement can be seen in figure 37. In these examples, the dynamic object can create closure with the static objects. As before, the line represents the movement of the dynamic object during the initial seconds.

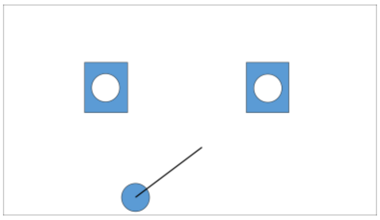


Figure 37 - Continuation with closure example

Examples of the "patterned movement" can be observed in Figure 38

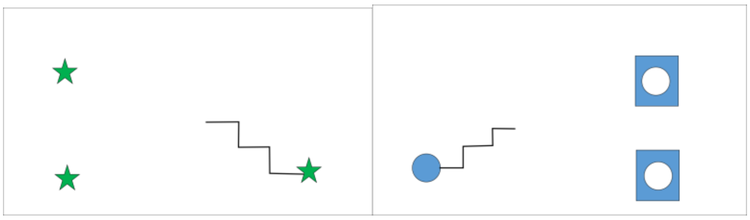


Figure 38 – Continuous, patterned movement examples

Lastly, Figure 39 demonstrates the last type of movement, the "random movement."

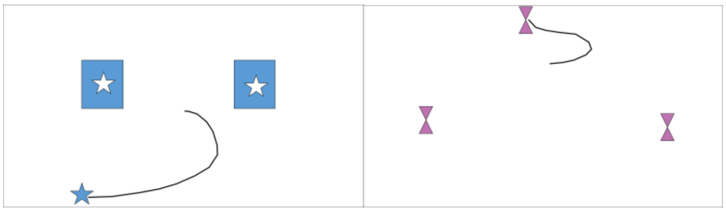


Figure 39 – Continuous, random movement examples

In addition to the type of the movement, there are two more parameters: the size of the movement (short/long), as shown in Figure 40.

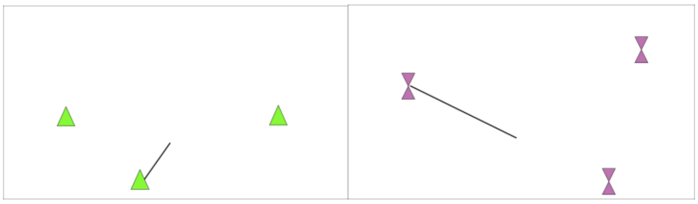


Figure 40 - Continuous, different sizes of movement

And the second parameter – the objects that exist in the movement's track as shown in figure 41.

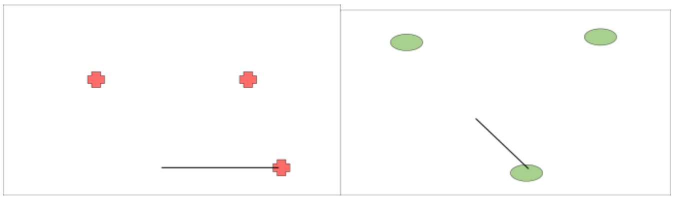


Figure 41 - Continuous, object in movement's track

Table 5 provides a review of the different variants tested, acknowledging that not all combinations were covered. Further investigation is necessary to explore the missing parts. Of particular importance is the variant that is not addressed in this study, wherein the number of static objects is not two. In this case, there may be influence to the number which creates different dynamics in the space.

Variant ID	Static object exists in the movement track	Movement type	Movement size	Static object – closure or identical
1	Yes	All	5cm - 9cm	Identical
2	Yes	All	4cm - 11cm	Closure
3	No – direction between objects	Static and patterned	3cm - 8cm	Identical

4	No – no specific place	Static	5cm - 8cm	Identical
5	No – direction between objects	Static	2.5cm	Closure
6	No – no specific place	Static	7cm - 7.5cm	Closure

Table 5 - Continuous different variants

Different directions of movement and diverse start positions were taken to avoid bias.

3.5.6. Other controlled conditions

Another controlled condition we addressed in this study was the Start Position or the Anchor, where the moving object appears in relation to the other objects within the 2-dimensional world. This property is a more general one, not related to Gestalt Laws, and relevant to all characteristics mentioned above. In each one of the afore mentioned characteristics, in addition to the relevant properties examined, the Start Position was taken into account as an additional parameter. Different positions were selected as the Start Position of the moving object to assess their potential impact on the decision-making processes.
The main Start Positions chosen for evaluation were: bottom in the middle, top in the middle, middle, left in the middle, left in the bottom, left up, right in the middle, right in the bottom, and right up. These positions are depicted by the "+" symbols in Figure 42.

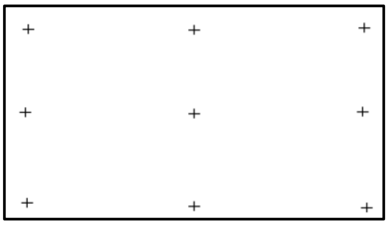


Figure 42 - "start position" places

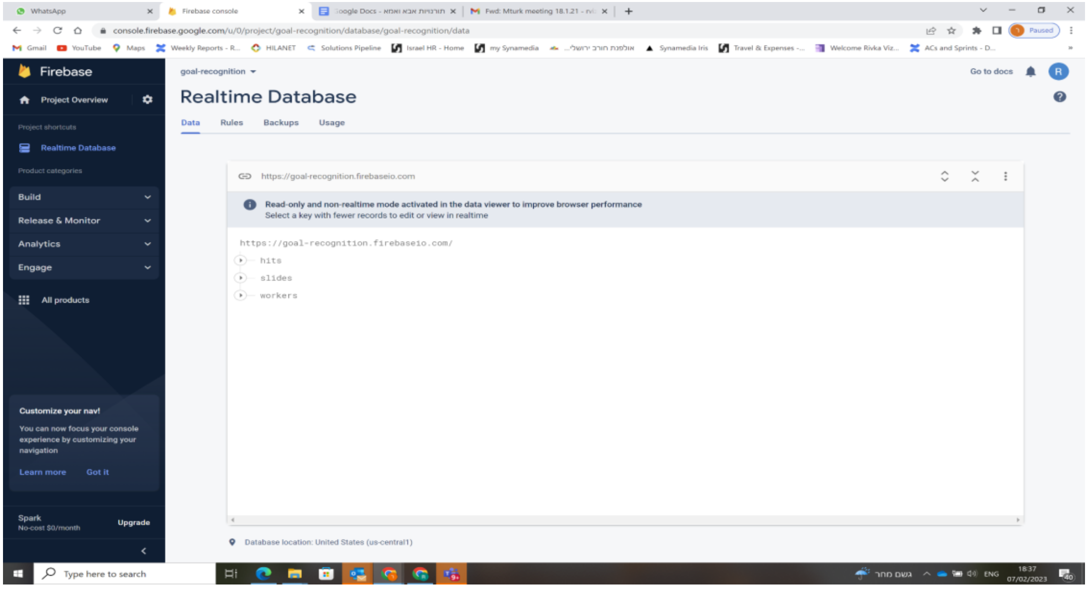
3.6. Data Collection and Curation

As part of the experiment, relevant data was collected and stored for each experimenter and experiment, enabling further analysis.

3.6.1. Raw data storage

The data was stored in Json format (see appendix) and was kept in the Firebase real-time Database, a free permanent storage solution (https://firebase.google.com/products/realtime-database). It was organized in a well-defined structure, and accessible only to authorized people, defined by the owner. The same data was stored in goggle driver with read permissions to all– see appendix.

The data is stored in three segments: experimenters (workers), experiments (hits), and pictures (slides).



Upon successful completion of the experiment by the experimenter, the following data is stored:

1. In the experimenter segment:
   - Personal data about the experimenter, including age, gender, and dominant hand. This data was collected at the start of the experiment.
   - Assignment ID assigned to the experimenter by Mechanical Turk.
   - Experiment output, as stored in the other segments described below.
   - Textual comments added by the experimenter at the end of the experiment are also stored, if any.
2. In the experiment segment, the following relevant data was stored:
   - Common data to all experiments:
     - The duration of the experiment in seconds
     - review status -??
     - title - "goal recognition"
     - Type ID - 36G9MO4VBAYPF81T3NI4CU9HA8LA3Z"
     - status – disposed
   - Unique data for each experiment, including:
     - unique ID of the experiment
     - Creation time
     - Expiration time
     - AutoApprovalDelayInSeconds - ??
     - experiment Group ID
     - experiment status (disposed/reviewable)

- Reward
- Max assignment - 1/0

3. The picture segments. For each picture that appeared in the experiment the following data is stored:
    - Experimenter ID.
    - Assignment ID.
    - Initial locations (x, y) of the static and the dynamic objects.
    - Final location (x, y) of the dynamic object.
    - Track of the dynamic object: the collection of (x, y) coordinates and their time) and time elapsed???

3.6.2. Handling invalid data

To avoid noises, non-valid data and partial data, we stored data only for experiments that were fully completed, i.e. all pictures were reviewed by the experimenter and decisions were taken for each one of the pictures (skip on a picture without moving the dynamic object also considered as a decision). 33 out of 910 did not complete the experiment and their results were not stored for further analysis.

3.6.3. Data processing: recreating the subjects' movements

The most intriguing aspect of the data pertains to the information stored in the "slides" folder. This dataset captures the decisions made by the various experimenters. It encompasses the track of the dynamic object's movement, the coordinates of its final location, and the quarter number of the final location.

Upon completion of the last experiment, the data from the "slides" folder was converted from JSON to SVG format to facilitate analysis. Consequently, a collection of SVG files was generated for each picture, which represents the results of the experiment.

All SVG files follow a consistent structure: they contain descriptions and locations of the static objects, and for the dynamic object, they include its description, initial location, full movement trajectory, and final location.

4. Experiment results and analysis

4.1. Experiment results

Two rounds of experiments took place. The first round took occurred on 13-14/July/2022, and the second round occurred on 18-22/November/2022. Nine hundred and nine experimenters executed the experiment. Thirty-three experimenters did not complete the experiment and their results were not stored for further analysis. Out of the remaining 876, 872 received bonuses as they moved the dynamic objects in all tasks they were assigned. The same analysis was conducted for all 876 experimenters, regardless of whether they received a bonus or not.

The average age of the 876 experimenters who completed the experiment is 39.5, with a standard deviation of 4.242641. Out of 876 experimenters who completed the experiment, 447 were females, 427 were males, and two selected "other" as their gender. Additionally, 41 reported left-hand dominance, 833 reported right-hand dominance and 2 chose "other" for hand dominance.

The results of the 876 experimenters were stored in the FireBase application, as described in section 4.6.1.

4.2. Results analysis

Below, we present the results of the analysis of the data collected for each of the main Gestalt principles. It should be noted that the extensive dataset allows for additional analysis in future work, such as investigating how subjects handled situations where Gestalt principles were in conflict.

For each of the characteristics, the results were categorized into four main categories:

- **No movement** – The experimenter did not move the dynamic object from its initial position.
- **Fit** – The location fits the characteristics, such as when the dynamic object creates symmetry with another object in case of the symmetry characteristic.
- **Contra fit -** The location contra-fits the characteristics, such as when the object moves to an object with a different color in cases of similarity.
- **No fit** - Other locations that do not fit the characteristic, for example, when the dynamic object does not move to any one of the objects in the space in cases of similarity.

4.2.1. Similarity

As described in Chapter 3, the experiment was conducted to examine sub-characteristics of color, shape, and size, as well as the cases of conflicts between them. The first step was testing each sub-characteristic separately.

Color

The first sub-characteristics examined was color. While shape and size remained identical in all objects, the colors were different. Only one static object had the same color as the dynamic object. The results are as follow:

- **Fit** – The dynamic object was moved to an identical object: 82%
- **Contra-fit** – The dynamic object was moved to a static object with a different color: 9%
- **No fit** – The dynamic object was moved to a position not categorized as “Fit” or “Contra-fit,” for example, it moved to a position between the static objects: 1%
- **No movement:** 8%

Figure 43 summarizes the results.

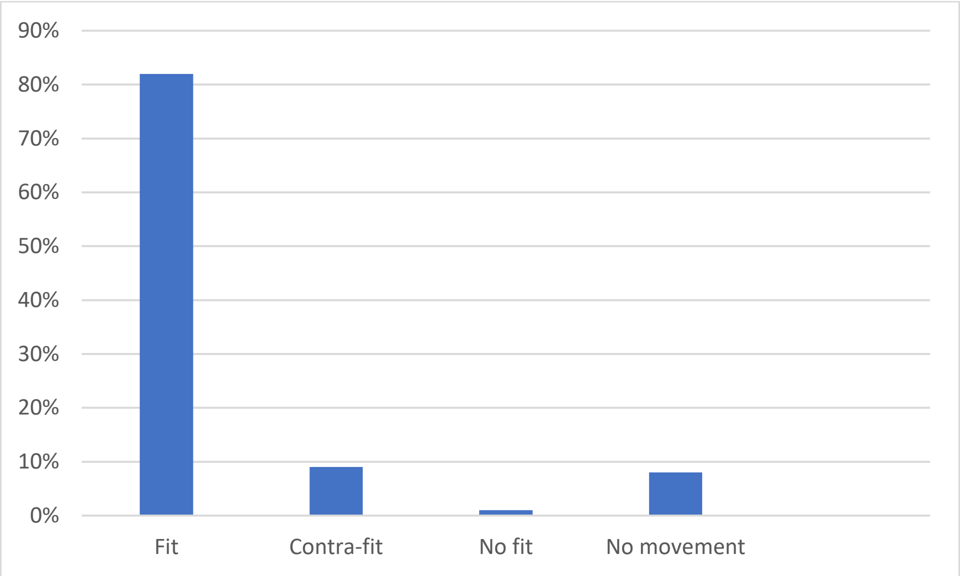


Figure 43 - Similarity Color results

Size

The same procedure was conducted for the size sub-characteristic. The results are as follows:

- **Fit** – The dynamic object was moved to an identical object: 90%
- **Contra fit** – The dynamic object was moved to a static object but with a different size 2%
- **No fit** – The dynamic object was moved to a position not categorized as “Fit” or “Contra-fit”, for example, it moved to a position between the static objects: 6%

- **No movement:** 1%

Figure 44 summarizes the results.

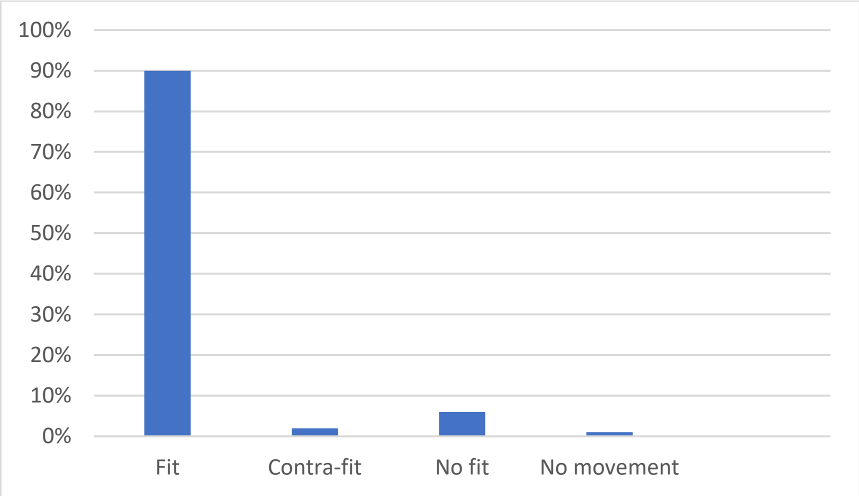


Figure 44 - Similarity Size results

Shape

Lastly, the experiment was carried out for the shape sub-characteristic. The results are as follows:

- **Fit** – The dynamic object was moved to an identical object: 87%
- **Contra fit** – The dynamic object was moved to the similar object but with a different shape: 4%
- **No fit** – The dynamic object was moved to a position not categorized as "Fit" or "Contra-fit": 8%
- **No movement:** 1%

Figure 45 summarizes the results.

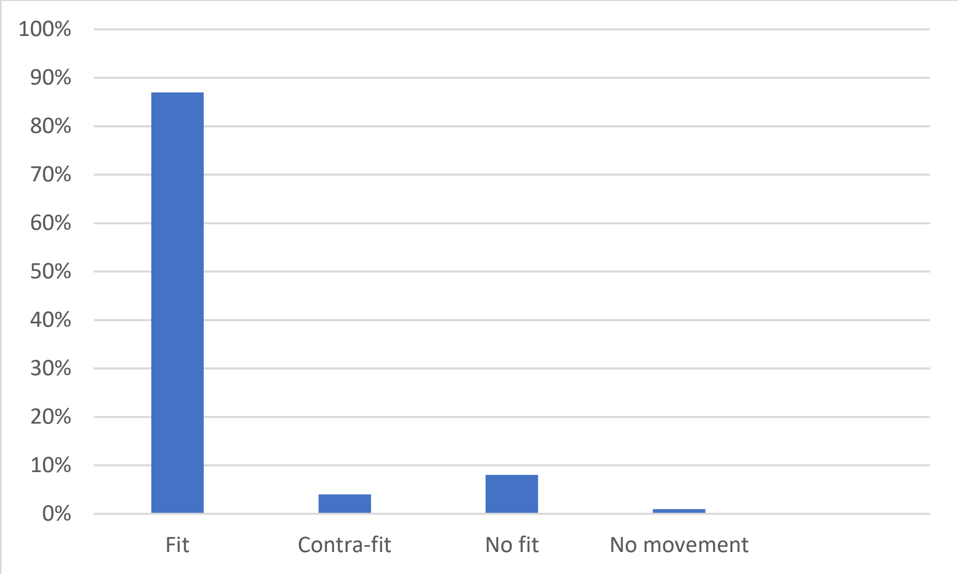


Figure 45 - Similarity Shape results

From the results, it is evident that there is a clear preference for targeting the dynamic object to an object with the same characteristic. This pattern holds true for all three sub-characteristics: color (82%), size (90%), and shape (87%).

4.2.1.1. Similarity Sub-characteristics conflicts

The next step involved analyzing conflicts between the sub-characteristics to determine their priorities.

Two patterns of conflicts were tested as mentioned in chapter 4.5.1

1. The first pattern tests priority between two sub-characteristics, X and Y. There are three types of conflict – shape-size, shape-color, and size-color. However, only the first two were tested in the experiment.
2. The second pattern tests the effect of the number of identical sub-characteristics. Several different options exist, but only the shape-size vs. size was tested.

The first pattern conflict – shape-size conflict:

This conflict occurs when the dynamic object is identical in shape and color to one static object and identical in size and color to another static object.
The results for this conflict are as follows:

- **Fit - same shape** – The dynamic object was moved to the object with identical shape: 83%
- **Fit - same size** – The dynamic object was moved to the object with identical size: 5%

- **No fit** - The dynamic object was moved to a position not categorized as "Fit - same shape" or "Fit - same size": 8%
- **No movement:** 2%

Figure 46 displays the results of the shape-size conflict

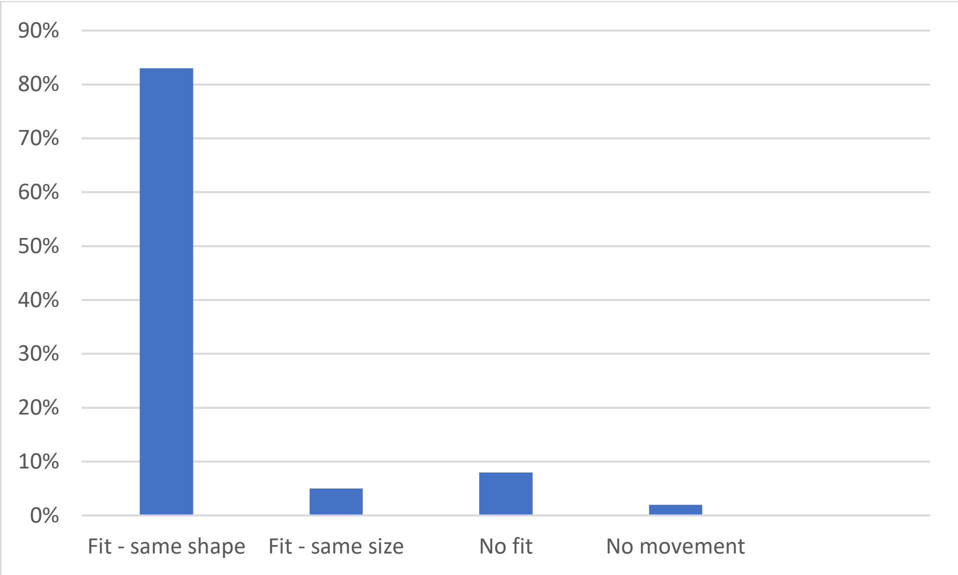


Figure 46 - Similarity, Shape-Size conflict results

Shape-color conflict

This conflict occurs when the dynamic object is identical in shape and size to one static object and identical in color and size to another static object.
The results for this conflict are as follows:

- **Fit - same shape** – The dynamic object was moved to the object with identical shape: 72%
- **Fit - same color** – The dynamic object was moved to the object with identical color: 12%
- **No fit** - The dynamic object was moved to a position not categorized as "Fit - same shape" or "Fit - same color": 12%
- **No movement:** 3%

The results of shape-color conflict can be seen in figure 46

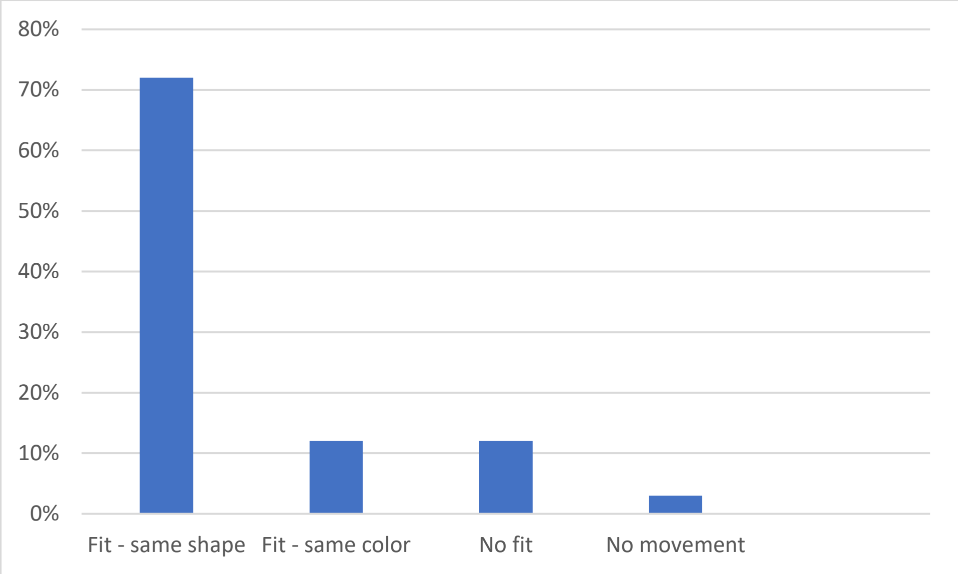


Figure 47 - Similarity, shape-color conflict results

From the last two conflicts, it is evident that shape is preferable over color and size. However, in the shape-color conflicts, the percentage of "no fit" was almost twice, and the shape was less frequently targeted.

The second pattern conflict:

The second pattern refers to the analysis of conflicts between the amount of similar sub-characteristics, but only the shape-size vs. size was tested.

The results for this conflict, where the targeted objects were those with the maximum sub-characteristics that match the dynamic object's sub-characteristics, are as follows:

- **Fit - same shape** & **same size** – The dynamic object was moved to the object with identical shape and size: 85%
- **Fit - same size** – The dynamic object was moved to the object with identical size: 3%
- **No fit** - The dynamic object was moved to a position not categorized as "Fit - same shape & same size" or "Fit - same size": 10%
- **No movement**: 2%

The results for this conflict can be observed in Figure 48.

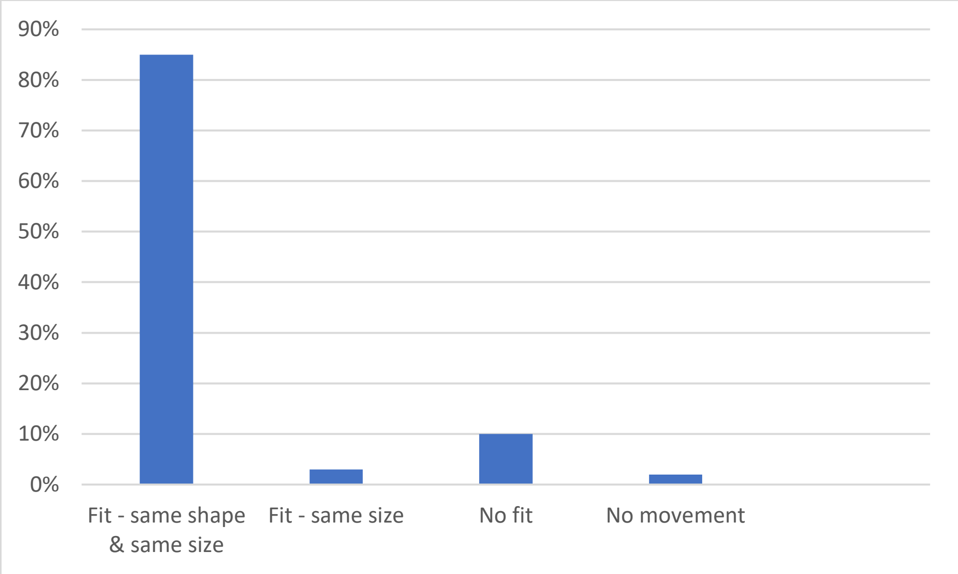


Figure 48 - Similarity, Shape&Size - Size conflict results

4.2.1.2 Similarity – Conclusions:

1. Each of the sub-characteristics obtained more than 80%, clearly indicating that similarity in color, shape, and size significantly affects goal recognition.
2. In case of conflicts, the priority order is as follows: shape has the highest priority, followed by color-size, although the priority between color and size was not tested in this experiment.
3. Further investigation is needed to determine the priority between targets with X sub-characteristics and targets with Y sub-characteristics, where X > Y.
4. The "no fit" results revealed two scenarios:

   a. The dynamic object was moved to a position between the static objects with similar distance to both objects.

   b. There were only a few cases where the object was moved to a position not related to the static objects.
5. The position of the dynamic object was moved in relation to the static objects, regardless of whether they had the same or different sub-characteristics:

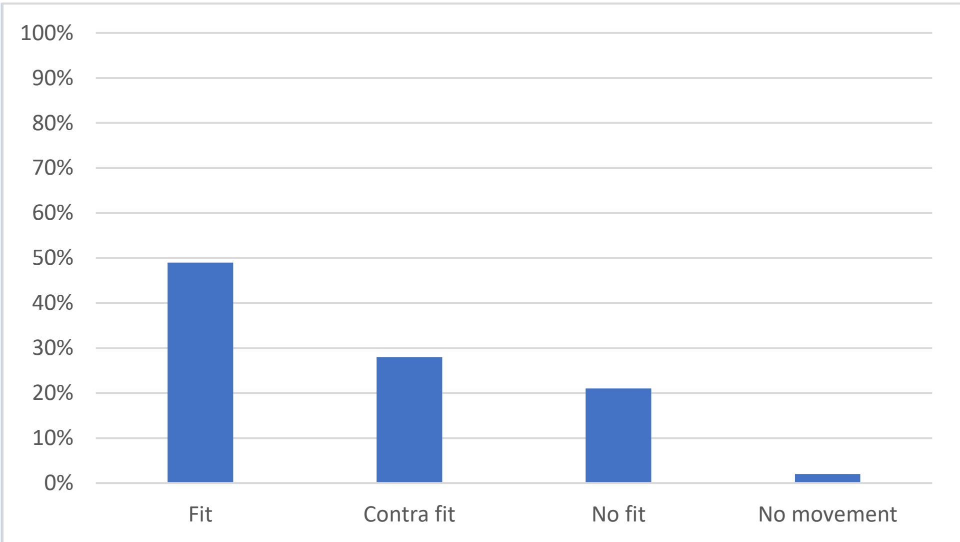
   When the static objects were in specific order, the dynamic object was moved to a position that, in most cases, aligned with order. For example, when the static objects were ordered in virtual row/column, the dynamic object was moved to the left/right or top/bottom of the first/last object or on top of one of the static objects in such a way that after the movement, the virtual row/column was saved.

4.2.2. Proximity

Proximity is a simpler characteristic than Similarity. The focus of the experiment was on the distance of the dynamic object from the static objects in 2-dimensional space. As described in the previous chapter, several variants were tested. This section describes the results of each one of them.

Variants 1-3 – Single static object/Group with minimal distance:

The results for variants 1, 2, and 3 are presented in figures 49, 50, and 51, respectively.



jFigure 49 - Proximity first variant results

Variant 1 Results:

- **Fit -** The dynamic object was moved to the object with the shortest distance: 49%
- **Contra-fit** - The dynamic object was moved to object that does not have the shortest distance: 28%
- **No Fit -** The dynamic object was moved to a position not categorized as “Fit” or “Contra fit”: 21%
- **No movement:** 2%

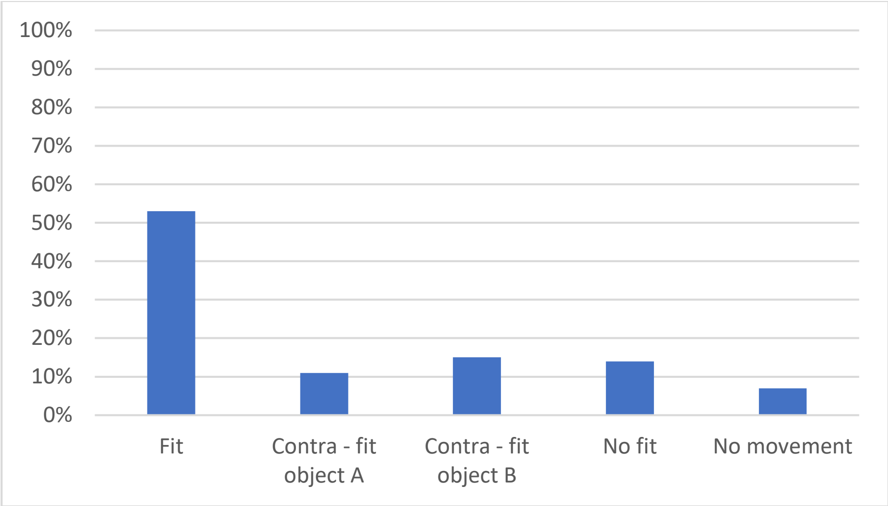


Figure 50 - Proximity second variant results

Variant 2 Results:

- **Fit -** The dynamic object was moved to the object with the shortest distance: 53%
- **Contra fit** - The dynamic object was moved to an object which does not have the shortest distance: 26%
- **No Fit -** The dynamic object was moved to a position not categorized as "Fit" or "Contra fit": 14%
- **No movement:** 7%

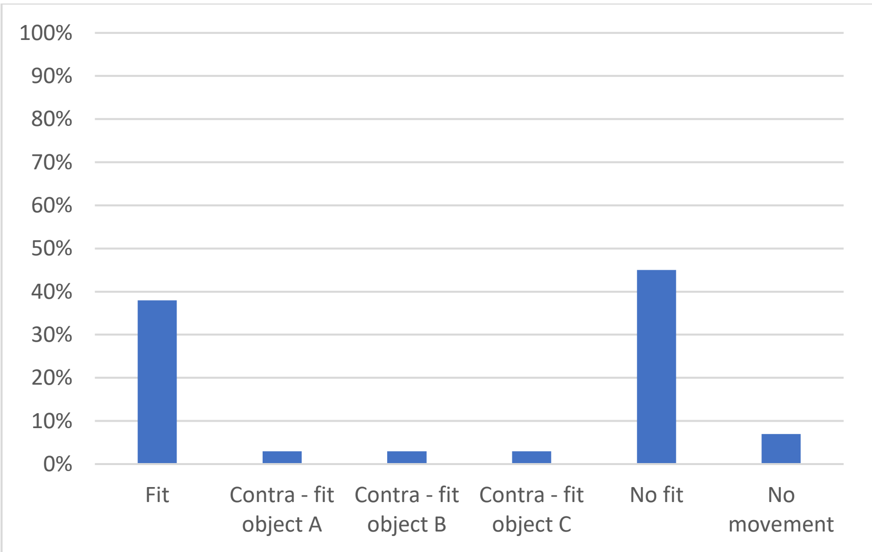


Figure 51 - Proximity third variant results

Variant 3 Results:

- **Fit -** The dynamic object was moved to the object with the shortest distance: 38%
- **Contra fit** - The dynamic object was moved to object which does not have the shortest distance: 9%
- **No Fit -** The dynamic object was moved to a position not categorized as "Fit" or "Contra fit": 45%
- **No movement:** 7%

From these results, it can be observed that in most cases (17 out 22 pictures), the preferable distance was the shortest one. However, the percentages varied across the variants, with 50% of the cases for Variant 1, 53% of the cases for Variant 2, and 38% of the cases for Variant 3.

Some additional interesting findings include:

1. Each one of the static objects was chosen.
2. As the number of static objects without the shortest distance increases, the "no fit" option also increases, nearly reaching 50% in some cases.
3. In cases where "no fit" occurred, the dynamic object was mostly positioned between two groups, in the middle.

Variants 4-5: Multiple static objects/Groups all with same distance

The results for variants 4 and 5 are presented in Figures 52 and 53, respectively.

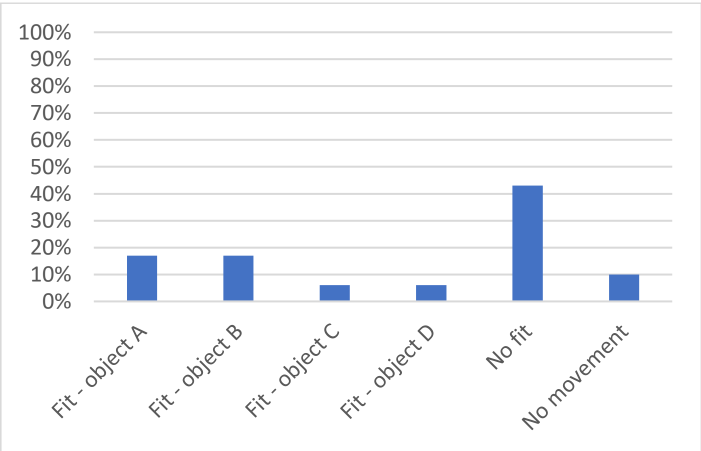


Figure 52 - Proximity fourth variant results

Variant 4 Results:

- **Fit** – The dynamic object was moved to one of the objects with the shortest distance: 46%
- **No fit** - The dynamic object was moved to a position not categorized as "Fit": 43%
- **No movement:** 10%

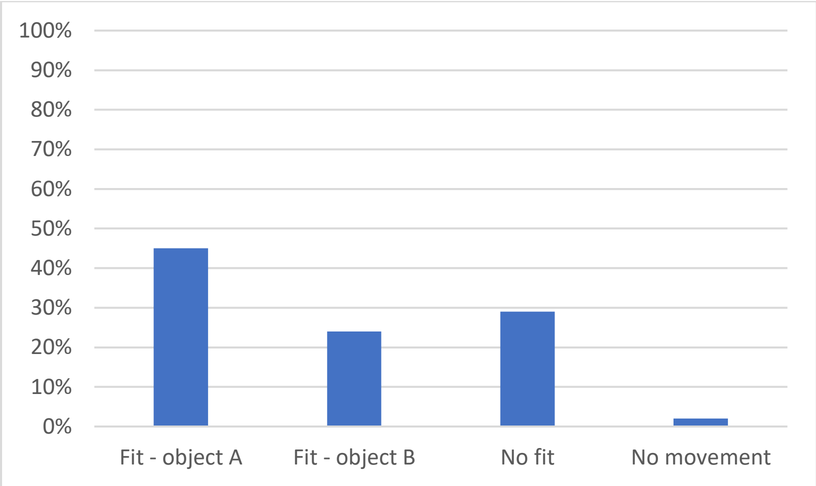


Figure 53 - Proximity fifth variant results

Variant 5 Results:

- **Fit** – The dynamic object was moved to one of the objects with the shortest distance: 69%
- **No fit** - The dynamic object was moved to a position not categorized as "Fit": 29%
- **No movement:** 2%

Some interesting findings from these results are:

1. Each one of the static objects was chosen.
2. There is no equal distribution among the objects.
3. As the number of static groups with the same distance increases, the "no fit" option also increases, surpassing 50% in some cases.
4. In cases where "no fit" occurred, the dynamic object was often positioned between two objects, in the middle.

Variants 6-7: Multiple static objects/Groups few with the shortest distance

Variants 6 and 7 involve cases where there are two or more objects or groups with the shortest distance from the dynamic object, but at least one object has a larger distance.

The results for variant 6 are presented in Figure 54.

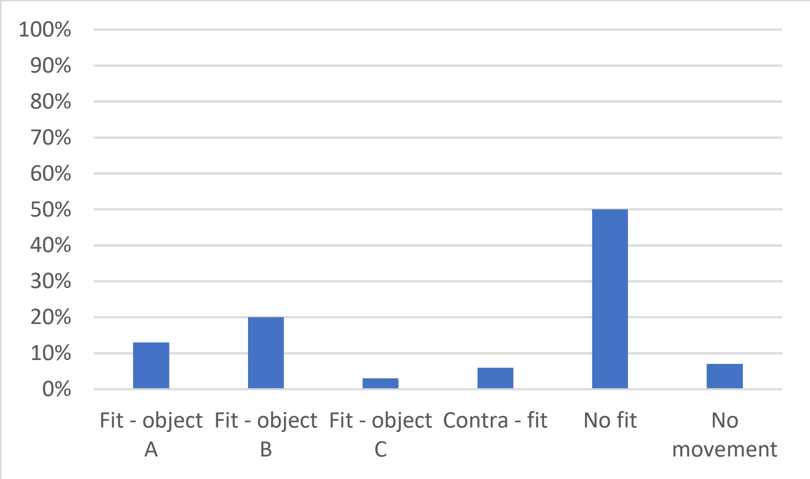


Figure 54 - Proximity sixth variant results

Variant 6 Results:

- **Fit** – The dynamic object was moved to one of the objects with the shortest distance: 36%
- **Contra Fit -** The dynamic object was moved to an object which does not have the shortest distance: 6%
- **No Fit -** The dynamic object was moved to a position not categorized as "Fit" or "Contra fit": 50%
- **No movement:** 7%

The results for variant 7 are presented in Figure 55.

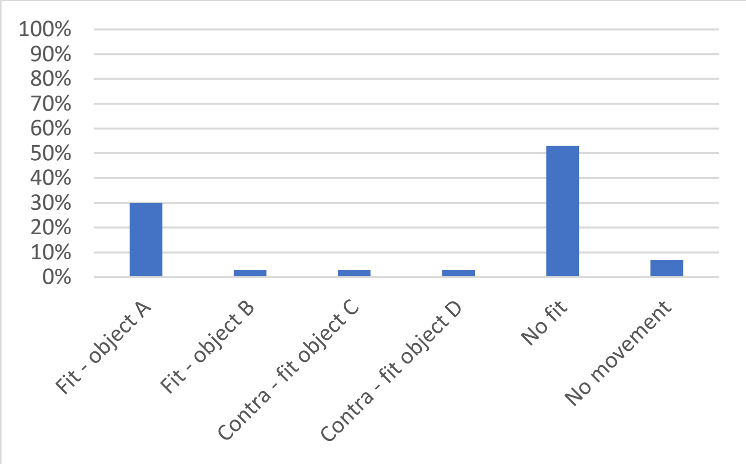


Figure 55 - Proximity seventh variant results

Variant 7 Results:

- **Fit -** The dynamic object was moved to one of the objects with the shortest distance: 33%
- **Contra Fit -** The dynamic object was moved to object which does not have the shortest distance: 6%
- **No Fit** - The dynamic object was moved to a position not categorized as "Fit" or "Contra fit": 53%
- **No movement:** 7%

In these variants, the majority of decisions resulted in the "no fit" option, with 50% for variant 6 and 53% for variant 7. Moreover, the sum of cases where the short distance group was chosen was significantly higher than the longer distance group (33% vs. 6% for variant 6 and 36% vs. 6% for variant 7).

The same list of interesting findings mentioned before are relevant to this case.

Variants 4, 5, 6, and 7 indicate that when multiple groups have the shortest distance, a significant number of experimenters opted for the "no fit" choice, often placing the dynamic object between two static groups.

Variants 8: Single group of objects with different distances

In this variant, there is one group of objects, and the dynamic object has different distances to each member of the group. The results for variant 8 are presented in Figure 56.

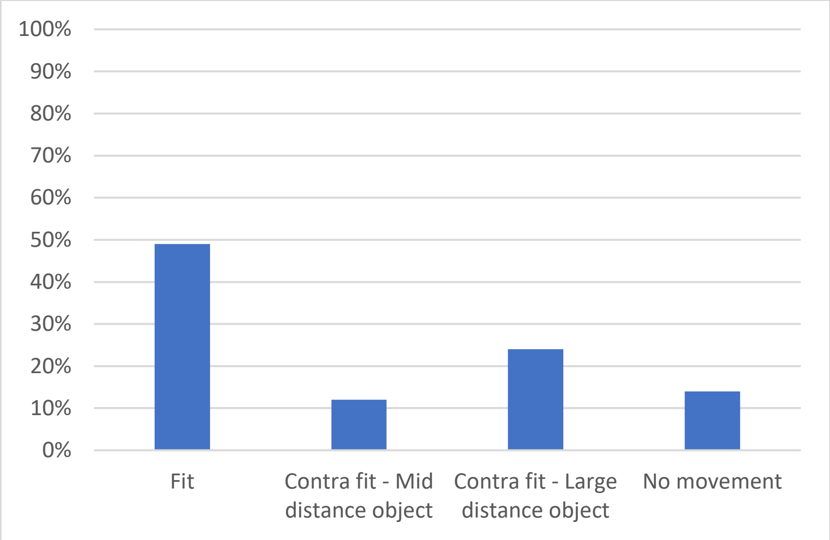


Figure 56 - Proximity eighth variant results

Variant 8 Results:

- **Fit** - The dynamic object was moved to the closest object in the group: 49%
- **Contra fit - large distance object** – The dynamic object was moved to the object with the largest distance: 24%
- **Contra fit - mid distance object** – The dynamic object was moved to the object with no middle distance: 12%
- **No movement:** 14%

4.2.2.1. Proximity – Conclusions:

The results for the proximity characteristic suggest that it is not as decisive as the similarity characteristic. Specific conditions need to be met for confidence in incorporating proximity into the formula.

Insights from the experiment to define these conditions are as follows:

1. The "short distance" option crossed the 50% threshold only when there were no more than two objects with the shortest distance. Further investigation is needed to determine the exact set of parameters for a clear decision on the shortest object.
2. As the number of static objects increases, the "no fit" option becomes more prominent, exceeding 50% when there are four objects.
3. In cases of "no fit," the dynamic object was often positioned between two objects, in the middle, in 87% of the cases.

4. When two or more objects have the same distance, there is no equal distribution between these objects. There is bias to specific objects which need additional exploration.
5. The starting position of the dynamic object affects the target choice. In some cases, two identical pictures with differences in the dynamic object's start position produced different results, with a significant gap between the short-long distance results, and in one case, the gap was opposite. This needs further investigation.
6. Each one of the static objects was chosen, likely because they all had the same similarity characteristics.

Additional Outputs and Insights:

Similarly to the previous characteristics: -

1. The "no fit" results have more than one possible position for the dynamic object:
   a. The dynamic object was moved to a position between objects with similar distance.
   b. There were only a few cases where the object was moved to a position unrelated to the static objects.
2. The position of the dynamic object was moved in relation to the static objects, regardless of their similarity or differences in the sub-characteristics:
   The static objects were located in specific order. The dynamic object was moved to a position that, most of the time, was aligned with order. E.g., when the static objects were ordered in virtual raw/column, the dynamic object was moved to the left/right or top/bottom of the first/last object, or on top of one of the static objects in such a way that preserved the virtual raw/column after the movement.

4.2.3. Symmetry

The Symmetry characteristic has several parameters, including Position, Level of symmetry, and the option of symmetry when multiple symmetry options are available. As mentioned earlier, there are seven groups that cover different combinations of these parameters. Let's examine the results of each group:

First Variant – Full symmetry -> Full/Partial/No symmetry

The initial state of the first group is fully symmetrical. The final state can be one of the following: full symmetry, partial symmetry, no symmetry, or no movement.

1. **Fit - full symmetry** – The dynamic object was moved to a position that created full symmetry: 72%

2. **Fit - partial symmetry** – The dynamic object was moved to a position that created partial symmetry around the X or Y axis, with the Y axis being chosen in most cases: 22%
3. **No symmetry:** 3%
4. **No movement:** 3%

Figure 57 displays the results of this group.

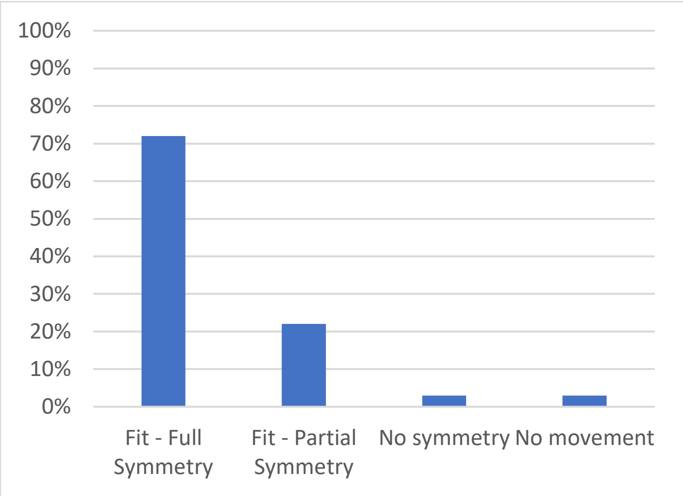


Figure 57 - Symmetry first variant results

Second Variant – Partial symmetry -> Partial/No symmetry

The initial state of the second group is partial symmetry. The final state can be one of the following: partial symmetry or no symmetry.

Results are displayed in figure 58

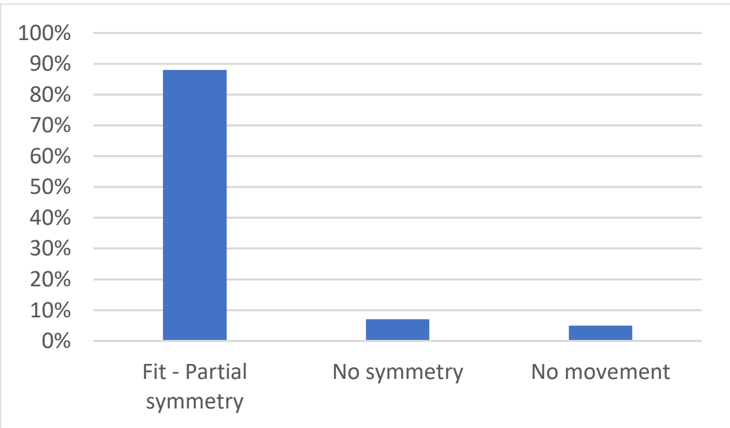


Figure 58 - Symmetry second variant results

1. **Fit - partial symmetry** – The dynamic object was moved to a position that created partial symmetry around the X or Y axis, with the Y axis being chosen in most cases: 88%
2. **No symmetry:** 7%
3. **No movement:** 5%

Some pictures have multiple options for partial symmetry. It is interesting to explore the preferred options in such cases. It was observed that in the majority of cases, the symmetry was around the axis that created partial symmetry with the static objects only. This requires further experimentation and analysis.

Third Variant – Partial Symmetry -> Full/Partial/No symmetry

The initial state of the third group is partial symmetry. The final state can be one of the following: full symmetry, partial symmetry, or no symmetry.

Figure 59 displays the results of this group.

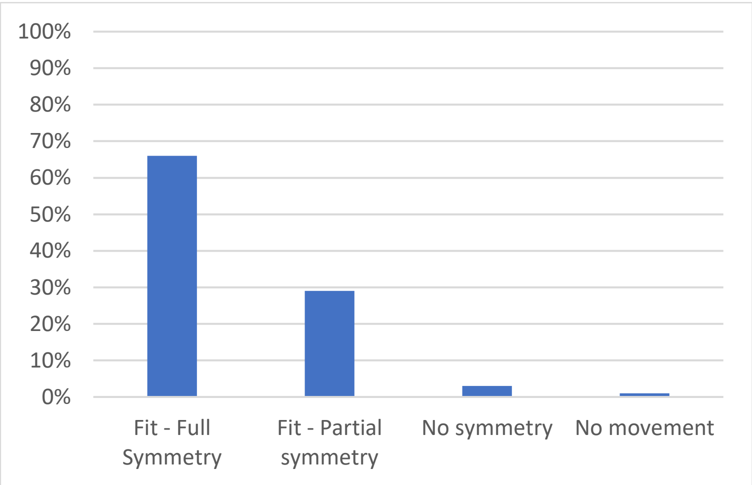


Figure 59 - Symmetry third variant results

1. **Fit - full symmetry**: The dynamic object was moved to a position that created full symmetry: 66%
2. **Fit - partial symmetry:** The dynamic object was moved to a position that created partial symmetry: 29%

3. **No symmetry:** 3%
4. **No movement:** 1%

It is worth investigating why the option of full symmetry is not chosen more often, and why experimenters prefer to create only partial symmetries in some cases.
As with the previous group, here also, the partial symmetry created was around the axis that formed partial symmetry with the static objects only, which warrants further investigation and analysis.

Fourth Variant – No symmetry -> Full/Partial/Mo symmetry
With the fourth group, the initial state has no symmetry. The final state can be one of the following: full symmetry, partial symmetry, or no symmetry.

Results can be seen in figure 60.

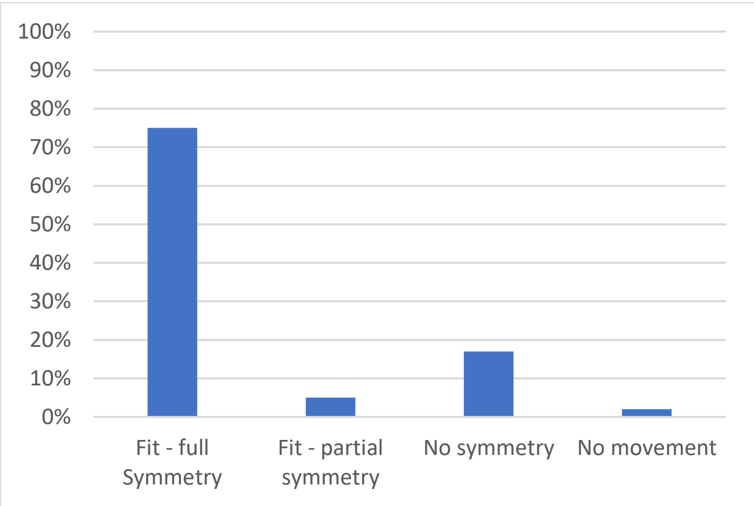


Figure 60 - Symmetry fourth variant results

1. **Fit - full symmetry** – The dynamic object was moved to a position that created full symmetry: 75%
2. **Fit - partial symmetry** – The dynamic object was moved to a position that created partial symmetry: 5%
3. **No symmetry:** 17%
4. **No movement:** 2%

As with previous groups, the question arises as to why the option of full symmetry is not chosen more often. Moreover, an interesting point for this group is the larger number of cases where the experimenter chose to place the dynamic object in a position that did not create any symmetry – 17% compared to other variants.

Fifth Variant – No Symmetry -> Semi partial symmetry

The initial state of the fifth group has no symmetry, and the final state can only have partial symmetry with one of the static groups (semi partial symmetry).

Results are displayed in figure 61

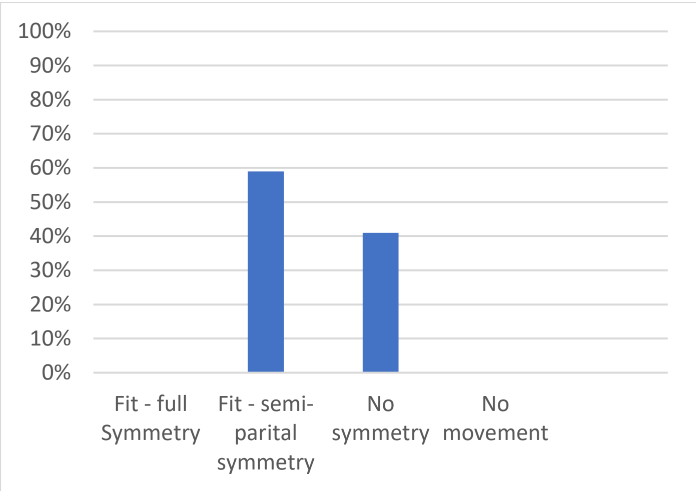


Figure 61 - Symmetry fifth variant results

1. **Fit - semi partial symmetry** – The dynamic object was moved to a position that created semi partial symmetry: 59%
2. **No symmetry:** 41%
3. **No movement:** 0%

We must approach these results with utmost caution, as they deviate from the classical symmetry and warrant further experimentation to elucidate the various semi-symmetry configurations.

Sixth Variant – No symmetry -> Partial symmetry

The initial state of the sixth group has no symmetry, and the final state can only be partial symmetry.

Results are depicted in figure 62.

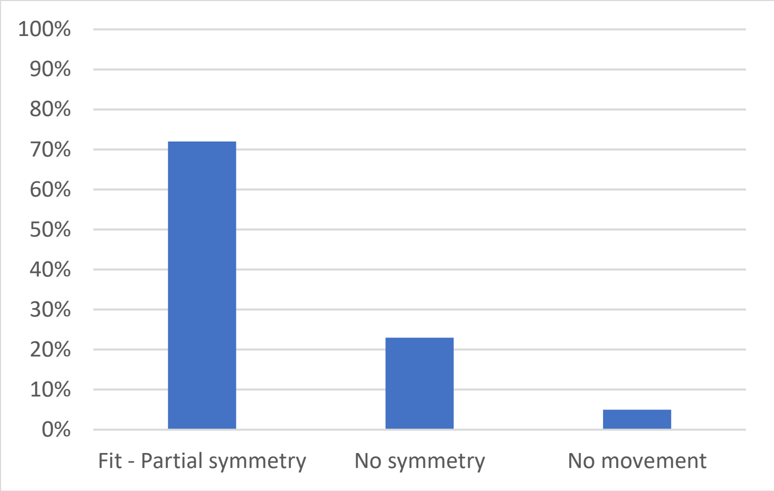


Figure 62 - Symmetry sixth variant results

1. **Fit - partial symmetry** – The dynamic object was moved to a position that created partial symmetry: 72%
2. **No symmetry:** 23%
3. **No movement:** 5%

When comparing this group to the others with classical symmetry options, it stands out as the sole group achieving less than 80% in "Fit" results.

4.2.3.1. Symmetry - conclusions

Upon considering all the results, it becomes evident that given the opportunity, and in the presence of options for full symmetry and partial symmetry, the experimenter would prefer to pursue full symmetry (approximately 70%) or, if not feasible, opt for partial symmetry (ranging from approximately 70% to 80%).

Regarding the positions to which the dynamic object was moved in cases where symmetry was absent, we could not find a template or systematic behavior. However, in the majority of the cases, the dynamic object was moved in close proximity or on top of one of the static objects.

4.2.4. Closure

The closure characteristics, as described in chapter 3, refer to the intention to complete missing parts in the objects. Four approaches were tested, as described in 4.5.4, and the results are presented below for each category.

First Variant -Known Shape Completion

In this variant, there is a standard shape with a missing part. Results can be seen in figure 63

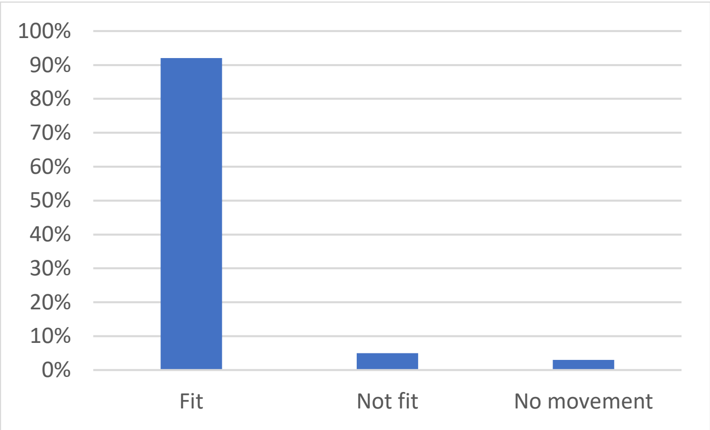


Figure 63 - Closure first variant results

1. **Fit:** 93%
2. **No fit:** 5%
3. **No movement:** 2%

Second Variant - Single Completion Option

In this variant, the dynamic object had a missing part. Figure 64 displays the results of this group.

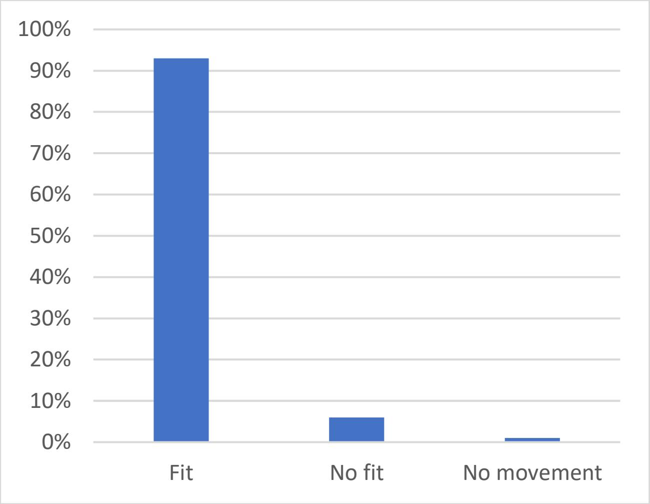


Figure 64 - Closure second variant results

1. **Fit:** 93%
2. **No fit:** 6%
3. **No movement:** 1%

Third Variant - Multiple Completion Options

In the third variant, the dynamic object fits the missing parts. Results can be seen in figure 65.

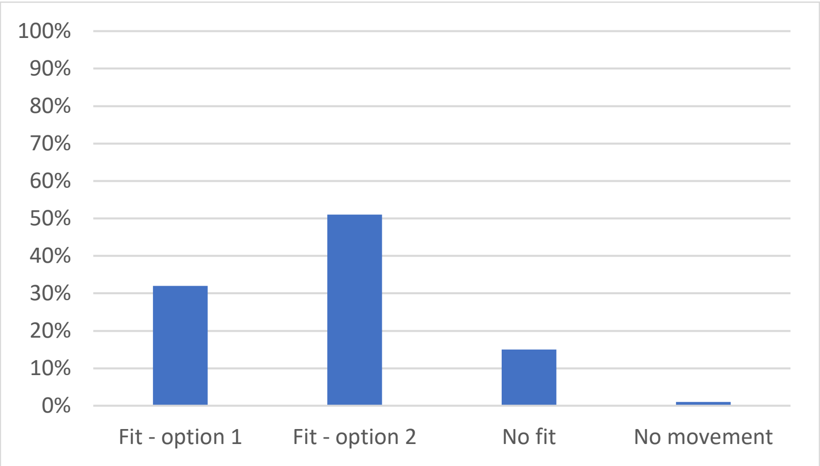


Figure 65 - Closure third variant results

1. **Fit -**
    1.1. First option: 32%
    1.2. Second option: 51%

2. **No fit:** 15%
3. **No movement:** 1%

Fourth Variant - Multiple no equal Completion Options

The fourth option involves the dynamic object fitting only one of the missing parts. Results can be seen in Figure 66.

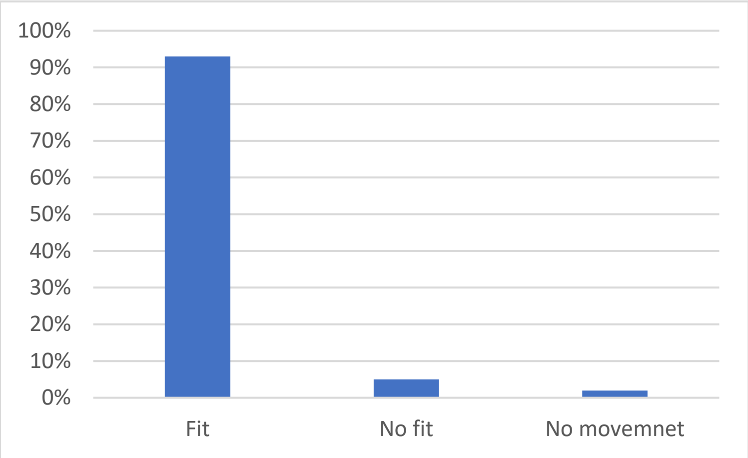


Figure 66 - Closure fourth variant results

1. **Fit:** 92%
2. **No fit:** 5%
3. **No movement:** 3%

4.2.4.1. Closure - Conclusions

Across all groups, the results are very similar, with the experimenter choosing to move the dynamic object to the missing part of the static objects in more than 90% of the cases, except the third group where there were more multiple options. The cumulative percentage for all options in the third group was 83%. Further investigation is needed to determine if the presence of multiple options influences the decision-making process and if the percentage changes with varying numbers of options.

Additional insights regarding the results:

1. In comparison to other characteristics, there were almost no cases where the experimenter did not move the dynamic object.
2. In the case of the third variant, the distribution between the options was not equal, as depicted in Figure 65. This discrepancy requires further investigation to understand its implications.

4.2.5. Continuation

The Continuation characteristic has several parameters, as mentioned earlier: the type of movement, movement size, whether a static object exists in the movement track, and if it exists, its type in comparison to the dynamic object (identical or closureness). Six variants were tested, each with different configurations of these parameters.

First Variant - Dynamic object moves toward identical static object

In this case, two static objects are identical to the dynamic objects. Various types of movements were tested, and the movements' size ranged between 5 cm to 9 cm.

The results are presented in Figure 67.

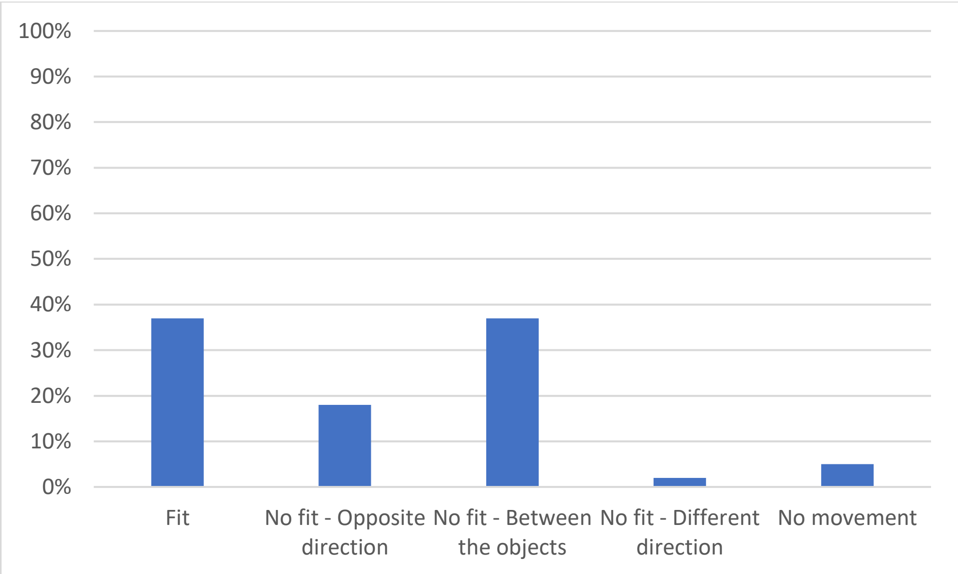


Figure 67 - Continuation first variant results

1. **Fit :** 37%
2. **No fit:**
   - b. **No fit - Opposite direction:** 18%
   - c. **No fit - Between the object**: 37%
   - d. **No fit - Different direction**: 2%
3. **No movement:** 5%

The results indicate that two main locations were selected by the experimenters in most cases (37% for each one):

1) Fit - Near or on top of the static object that exists in the movement's track.
2) No fit - Between the two static objects that appear in the picture.

Another interesting result is that some experimenters chose to place the dynamic object in the opposite direction of the movement, i.e., near or on top of the second static object that was not part of the movement track – 18% selected this option.

Additionally, when considering only the pictures with static movements, the percentages change to 42% for the "Fit" option and 33% for the "No fit - between the object" option. By further considering only the biggest size movement, the "Fit" option increases to 51%, the "No fit" option decreases to 29%, and the option of placing the dynamic object in the opposite direction reduces to 13%.

Second variant - Dynamic object moves toward closureness static object

In this scenario, two identical static objects create closure with the dynamic object. All types of movements were used, and the movement's size ranged between 4 cm to 11 cm.

The results are shown in Figure 68.

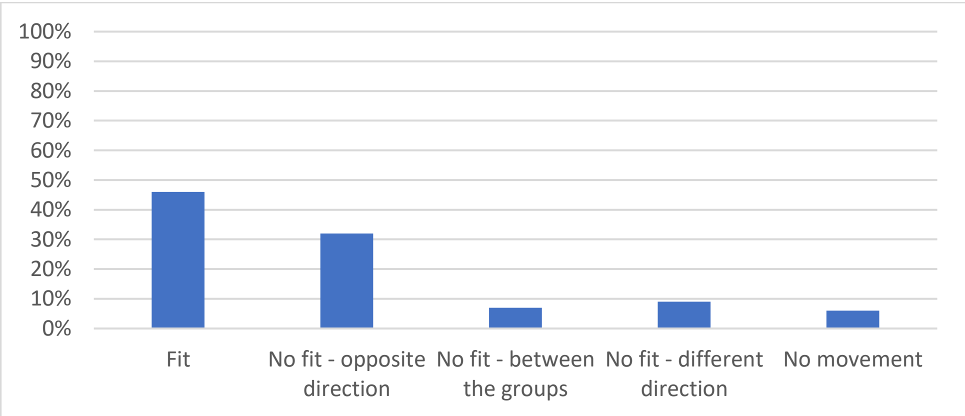


Figure 68 - Continuation second variant results

1. **Fit:** 46%
2. **No fit:**
   a. **No fit - Opposite direction:** 32%
   b. **No fit - Between the object:** 7%
   c. **No fit - Different direction**: 9%
3. **No movement:** 6%

The results were different from the first case. The two main placements for the dynamic object were as follows:
1) "Fit" - Creating closure with the static object that exists in the movement's track, accounting for 46% of the choices.
2) "No fit" - Creating closure with the static object that exists in the opposite direction from the movement's track, representing 32% of the choices.

Unlike the previous case, only 7% of the participants chose to place the dynamic object between the two static objects.

As in the previous case, here too, if we consider only the static movement, the "Fit" option increases to 57%, while the "No fit opposite direction" decreases to 30%. However, in this case, only short movements were performed for the static movements, so there is no data available to explore larger movements. The conclusions drawn from the first two variants are as follows:
Static movements and long movements tend to increase the likelihood of the static object that appears in the movement's track being chosen, but it does not exceed 60%.

Third variant - Dynamic object moves toward position between the identical static objects

This is the first case where the static objects are not in the movement's track. The dynamic object moves to a position between the two identical static objects. In this case, we used static and patterned movements, and the movement's size was between 3 cm to 8 cm.
The results can be seen in Figure 69.

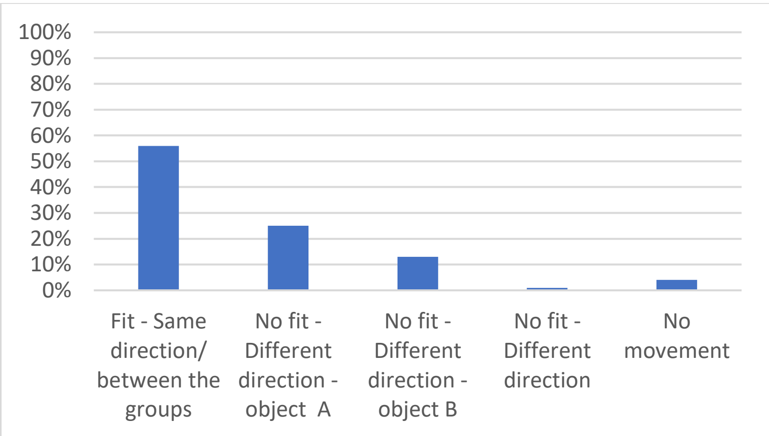


Figure 69 - Continuation third variant results

1. **Fit**: 59%
2. **No fit:**
    a. **No fit - Object A**: 25%
    b. **No fit - Object B**: 13%
    c. **No fit - Different direction**: 1%

3. No movement: 4%

Also here, if we consider only the static movements, the results of the first option increase to 66%.

Fourth Variant- Identical static objects are not in the dynamic object movement's track.

Similar to the previous case, the main differences are:

1) Movement was not targeted to static objects or to the position between them.
2) Only static movement was used, and
3) The movement's size was between 5 cm to 8 cm.

Results are in figure 70

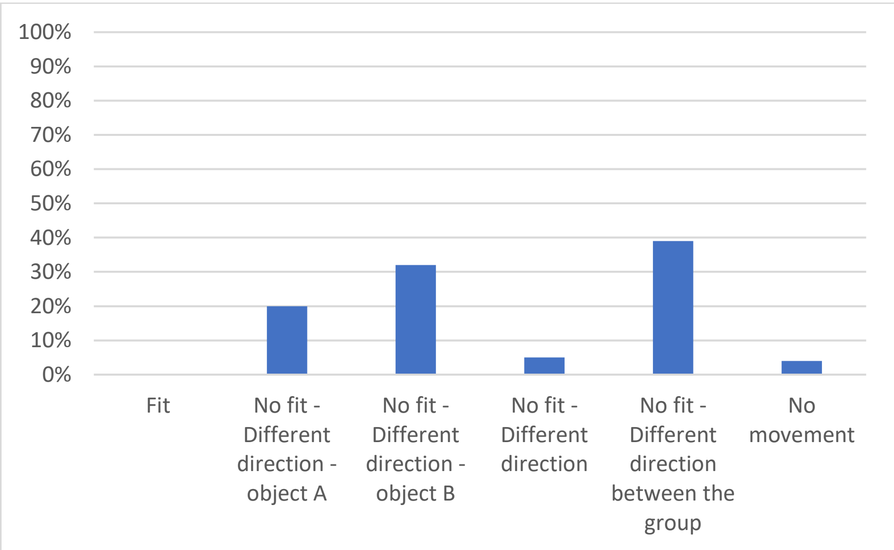


Figure 70 - Continuation fourth variant results

1. **Fit:** 0%
2. **No fit:**

    2.1. **No fit - Object A**: 20%

    2.2. **No fit - Object B**: 32%

    2.3. **No fit - Between the objects**: 39%

2.4. **No fit - Different direction:** 5%

3. **No movement**: 4%

Fifth Variant - Dynamic object moves toward position between two closureness static objects

The dynamic object moves to a position between the two static objects that creates closure with the dynamic object. In this case, we used only static movements, and the movement's size was 2.5 cm.

Results are presented in figure 71

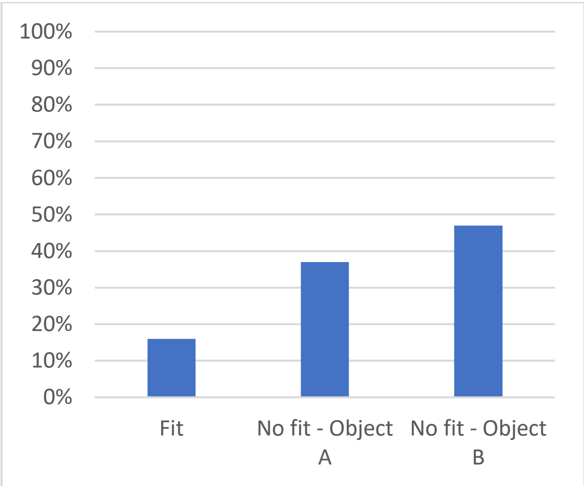


Figure 71 - Continuation fifth variant results

4. **Fit:** 16%
5. **No fit:**
   5.1. **No fit - Object A**: 37%
   5.2. **No fit - Object B**: 47%
6. **No movement:** 0%

The results show that in most of the cases, the experimenters chose to move the object to a position that creates closure with the static objects and ignored the direction of the movement. This is very different from the case where we had identical static objects, which can give hints about the priority between the two characteristics.

Sixth variant - Closureness static objects are not in dynamic object movement's track.

As in the previous case, the main differences are:

The movement was not a target to static objects or to the position between them, and the movement's size was between 7 cm to 7.5 cm.

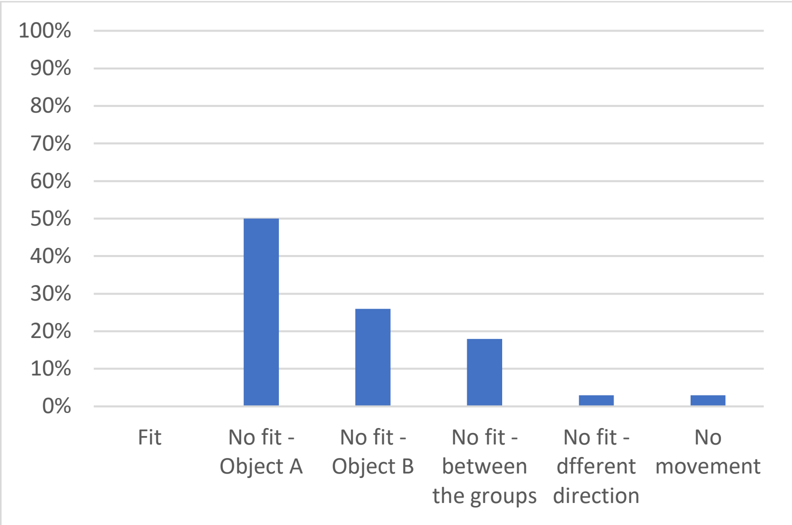


Figure 72 - Continuation sixth variant results

1. **Fit:** 0%
2. **No fit:**
   a. **No fit - Object A:** 50%
   b. **No fit - Object B:** 26%
   c. **No fit - Between the objects**: 18%
   d. **No fit - different direction:** 3%
3. **No movement**: 3%

The conclusions from the last four variants, where static objects are not in the movement's track are as follows:

1) The major results show that the experimenter chose one of the 2 options:
   a. Near or on top of one of the static objects.
   b. Between the static objects.

   This reflects the idea that humans prefer to move objects to a meaningful position.
2) In case the static objects create closure, the first option (closure with the object), increases dramatically.

4.2.5.1. Continuation - conclusions

The results can be divided into two main groups: (1) movement toward static objects and (2) movement toward positions with no static objects in the movement track.

For the first group, we observed that with static movements and the largest movements, we reached close to 60% preference for the "Fit" option, where the dynamic object fits with one of the static objects. The second option in this case is either "between the objects" or the 2nd object in the case of "closureness."

For the second group, we observed that the experimenters preferred to move the object to a "meaningful" position, which is near the static objects or between them.

5. Summary and Future Work

This research focuses on understanding the cognitive processes involved in human ability to comprehend the intentions of others, a process also known as goal recognition. The primary focus was on the perception element.

We built upon the Gestalt principles as a basis to comprehend the role of visual perception in goal selection. The set of elements tested includes Similarity, Proximity, Symmetry, Closure, and Continuation. The experiments were conducted using the Mechanical Turk platform. Each experiment included a set of pictures for each subject, with the primary task being to decide where to move the object in each picture. Each picture featured a set of elements representing one or more characteristics that were tested. The results for each subject were stored in a database and analyzed after the experiment was completed. The database is available for further research.

5.1. Conclusions

After analyzing the results, we found that the characteristics of Similarity, Proximity, Symmetry, Closure, and Continuation contribute significantly to our basic understanding and anticipation of goal recognition in a 2-dimensional world. Notable insights from each characteristic are as follows:

- **Similarity**

  We tested the different sub-characteristics (color, shape, and size) under similarity. For each one of them, the results show that humans have a clear preference for choosing objects that are identical in the sub-characteristics (color, shape, and size) to the object that needs to be moved to a chosen target. When conflicts arise, shape has a clear preference over color and size.

- **Proximity**

  Proximity is an important characteristic influencing decisions regarding the target object's movement. However, it is not as strong and absolute as similarity. In specific conditions, its salience weakens, especially when the number of objects in space increases. Additionally, the start position of the dynamic object also affects the decision, requiring further investigation.

- **Symmetry**

  The experiments showed that humans have clear and strong preferences to create symmetry by moving the object to a position that generates symmetry. If there are multiple options to create symmetry, humans tend to choose full symmetry options over partial symmetry.

- Closure

  The conclusions drawn from the closure experiments were very clear. Humans tend to move the object to a position that completes a missing part of a known shape, such as a circle, or to close a gap in a continuous object.

- Continuation

  The influence of the continuation characteristic on human decision-making is evident, but several conditions affect this influence. Firstly, the type of movement plays a significant role, with static, linear movements yielding the best results. Other types of movements led to decreased numbers of desired outcomes. Secondly, the length of the movement also plays a role, as increasing the movement length resulted in better results. Finally, the presence or absence of other objects in the movement's track affected the decisions. Humans prefer to move objects to positions where other objects already exist. If the movement is directed towards a position where no objects exist, the results were less satisfactory.

A general conclusion applicable to all characteristics is that in most cases where the experimenter didn't choose any object from the objects in the space, they moved the object to a position between two objects with identical distance from them.

There are still open areas that require clarification or future research. This chapter concludes with a brief summary of these topics.

5.2. Data for future work questions

5.2.1. Conflicts and Priorities

In this study, we investigated five characteristics based on five Gestalt principles - Similarity, Proximity, Symmetry, Closure, and Continuation. The experiment examined each characteristic separately while neutralizing others. Further investigation is needed to fully understand goal recognition and the conflicts and priorities that arise between the characteristics. The results obtained from this study do not allow us to determine the decisions made when there are multiple goals, each with different characteristics. The priority between them and the effects of having characteristic X in one goal and characteristic Y in other goal, where X and Y are different, remains unclear. The experiment included partial work on this area, but the results were not analyzed. The following section gives a high-level overview of these cases, that were part of the experiment. The data is contained in the database.

- Similarity and Proximity: The static object with similarity has a longer distance than the other static object.

- Similarity and Symmetry: One static object creates symmetry but lacks similarity, and the other is similar but does not create symmetry.
- Similarity and Closure: One static object creates closure, and the other has similarity.
- Similarity and Continuation: One static object in the movement's track, while the other is similar to the dynamic object.
- Proximity and Symmetry: Several combinations were tested:
  - Different static objects with different levels of symmetry and different distances.
  - Different static objects with the same level of symmetry and different distance.
  - One static object creates symmetry, but it has the longest distance compared to the others.
- Proximity and Closure: Different static objects with full or partial closure with different distances.
- Proximity and Continuation: The static object with the longest distance is on the movement track.
- Symmetry and Closure: One static object creates symmetry, and the other creates closure.
- Symmetry and Continuation: The static object that creates symmetry is not in the movement track.
- Closure and Continuation: The static object that creates closure is not in the movement track.

5.2.2. Decision – Additional Data

The experiment outputs provide valuable data that has not yet been fully analyzed. One area of interest is the data related to decision-making. For each result of each picture, we have recorded the time taken by the experimenter to decide where to place the static object and the track of the dynamic object until it reached its final position. Analyzing this data can offer deeper insights into the influence of different characteristics. For instance, examining the time taken for decisions in distance pictures may provide further support for the significance of the Proximity characteristic. Moreover, we have gathered data about the experimenters themselves, including their age, dominant hand, and other relevant information. It remains to be investigated whether any of these individual factors have an impact on decision-making during the experiment.

5.3. Future Work

The analysis of the different characteristics raised questions which were not deeply investigated or did not have enough data. In the following section, we will review these open questions.

5.3.1. Similarity

Further work is needed to be done with Similarity, mainly in the following areas:

1. Similarity has different sub-characteristics. We tested only color, size, and shape. Two other sub-characteristics, texture, and complex shapes, need to be tested in the same way that was done for color, size, and shape, including conflicts between texture, complex shapes, and the others.
2. Conflicts and priorities:
    a. Not all conflicts between the two sub-characteristics were tested. These tests could help establish the sub-characteristics priority list.
    b. The main pattern of conflict that was tested is the case in which static objects are not identical, and each one of them has the same sub-characteristics as the dynamic object except one sub-characteristic. Different patterns of conflicts need to be explored, e.g., each one of the static objects has a different number of sub-characteristics that are identical to those in the dynamic object.

5.3.2. Proximity

Understanding why the distribution is not equal when two or more static objects have the same distance requires additional research to identify underlying patterns or cognitive processes.

5.3.3. Symmetry

1. In symmetry, when there are several options to create symmetry or partial symmetry, the results suggested that most of the experimenters had a "favorite" option. It is not clear whether this is true for all cases, or why certain options become the "favorite." Further investigation is needed to answer these questions.
2. Another area which remains open is why experimenters chose to create partial symmetry if they have the option to create full symmetry.
3. A different case is the semi-symmetry case, which is not a typical symmetry case. Further work is needed regarding this case as well.

5.3.4. Closure

1. Analyzing why the results were not balanced between options when experimenters have more than one choice to create closure.
2. Investigating whether the number of options affects the sum of results that "Fit" the closure is also essential.

5.3.5. Continuation

The experiment mainly covered the basic elements of continuation: only two static objects, which are identical, or create closure and a limited size of movement. Additional elements and configurations need to be examined in order to strengthen the existing conclusion or provide new insights. The following set of parameters and configurations need to be tested:

- Different number of static objects, not equal to two: With two static objects, we observed that moving the dynamic object between these two static objects resulted in dominant outcomes. However, we need to investigate whether this dominance holds true when dealing with a different number of static objects.
- Focus on static movement with larger movement sizes: Our current results indicate that the length of the movement has an impact on the outcomes. To strengthen this conclusion, additional tests using larger movement sizes, especially larger ones, should be conducted.
- Static objects' characteristics should have different combinations, not limited to those mentioned before.

5.3.6. Start position

Different start positions of the dynamic object were chosen in all characteristics pictures to check if there is any effect of the start position. In all cases except for Proximity, we did not observe that different start positions caused different results, but this was only the case in the Proximity characteristic. To gain a more comprehensive understanding of the effect of the start position of the dynamic object, further investigation is required.

5.4. Three-dimensional world

Lastly, this work deals with questions about goal recognition in the 2-dimensional world only. To expand our understanding, future research should be conducted to explore whether the same Gestalt principles apply and provide answers in the context of a 3-dimensional world.

Appendices

Appendix A

Links to experiment code and data

Experiment code in git - https://github.com/rivkavizenexp/goal-recognition-2d

Experiment results (JSON format) - https://drive.google.com/drive/u/0/folders/1YjdVqZugsJOYNDWgpKUOkUuWxI_Tetp1

This folder contains 3 files:

- goal-recognition-workers-export.json – information about the experimenters
- goal-recognition-slides-export.json – information about results of each picture
- goal-recognition-hits-export.json – information about each experiment

For each of the above files a readme (with the same name) with explanations.

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