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Psychological processes of perceiving implied motion in static images

Abstract: The aim of this study was to investigate four sources of implied motion in static images (a moving object as the source of implied motion, hand movements of the image creator as the source of implied motion, past experiences of the observer as the source of implied motion, and fictive movement of a point across an image as the source of implied motion). In the experiment of the study, participants orally described 16 static images that appeared on the screen of a computer. The aim was to find whether participants had used any motion-related word to describe each image. It was assumed that using motion-related words to describe a static image was an indication that the image had created a sense of motion for the observer. These results indicated that all four types of implied motion could create a significant sense of motion for the observer. Based on these results, it is suggested that observing these images could lead to simulating the actions involved in those motion events and the activation of the motor system. Finally, it is proposed that the three characteristics of being rule-based (clearly-defined), continuous, and gradual are critical in perceiving that image as a fictive motion.

Keywords: *Static images; Implied motion; Motion event; The motor system*

1. INTRODUCTION

This aim of this study was to investigate implied motion in static images and the neuropsychological processes involved in observing such images. When we look at the photo of a running man, we immediately realize that it shows a motion event although no motion takes place in that static photo. Here, we attribute the feature of movement to a static object. In fact, based on our past experiences, we realize that the photo has been taken at a time when the man had been running. This is perhaps one simple example of implied motion in static images. Another photo may show a man who is standing in one point but is ready to run. Here, the body posture suggests that the man is going to run. This is another case of implied motion that is different from the first example. A number of studies have examined neural activities during perceiving pictorial stimuli showing implied motion (Kourtzi & Kanwisher, 2000; Lorteije et al., 2006, 2007, 2010; Osaka, Matsuyoshia, Ikeda, & Osaka, 2010; Senior et al., 2000; Williams & Wright, 2010; Winawer, Huk, & Boroditsky, 2008). The findings of some neuroimaging studies have suggested that the same cortical areas are involved in the process of observing real motion and observing pictorial stimuli containing implied motions (e.g., Kim & Blake, 2007; Kourtzi & Kanwisher, 2000; Osaka et al., 2010; Senior et al., 2000; Williams & Wright, 2010).

Pavan, Cuturi, Maniglia, Casco, and Campana (2011) found that viewing pictorial stimuli containing implied motion could involve the same direction-selective and speed-tuned mechanisms that are involved in observing real motions. Interestingly, two studies specifically focused on the processing of abstract works of art that contained implied motion. One study (Umilta', Berchio, Sestito, Freedberg, & Gallese, 2012) examined neural activities during viewing Lucio Fontana's paintings. This study provided evidence that suggests during observing abstract works of art that include implied motion, cortical motor system is activated. Another study (Sbriscia-Fioretti, Berchio, Freedberg, Gallese, & Umiltà, 2013) examined neural activities in sensorimotor cortical circuits when participants of the study looked at abstract works of art with marked traces of brushstrokes. A study conducted by Thakral, Moo, and Slotnick (2012) indicated that observing von Gogh's paintings is associated with the activation in MT+ region. Zhao et al. (2020) found that when people make aesthetic judgments on static and dynamic landscapes, supplementary motor area is activated. The findings suggested that premotor and motor cortical areas are activated during observing abstract works of art containing implied motion. In most of the mentioned studies, the pictorial stimuli showed a moving object/person or the posture of an object/person just before movement in a certain direction. But, these pictorial

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stimuli can be considered as one type of implied motion. In other words, we may think of other types of implied motion in pictorial stimuli that may have similar features in terms of processing. The following section classifies implied motions into four categories.

This study aimed to investigate sources of implied motion in static images. An experiment was conducted to examine how implied motions in static images are processed. This study specifically focused on four types of implied motion: 1) a moving object as the source of implied motion (e.g., the image of a running man), 2) hand movements of the image creator as the source of implied motion (e.g., the image of traces of brushstrokes), 3) past experiences of the observer as the source of implied motion (e.g., the image of a road), 4) imaginary movement of a point across an image as the source of implied motion (e.g., the image of a mountain range that goes from west to east of a country). It was hypothesized that these four types of implied motion create a sense of movement when an observer looks at them.

2. METHODOLOGY

2.1 Participants

Twenty university students were selected to participate in this study (13 females and 7 males). They were 17-23 years old. They did not have any eye-sight or neurological problems. All of them participated in the study voluntarily.

2.2 Materials and procedure

Sixteen static images were used in this study. Each four images included one type of implied motion. These images were carefully selected by researcher of the study. Each image appeared on the screen of a computer for a period of 30 seconds. During this time, participants had to describe each image orally. The voices were recorded by researcher of the study. After each item, there was a pause of 5 seconds. Then, the next item appeared on the screen. The images were shown on the screen randomly. Recorded voices were carefully examined by researcher of the study. The aim was to find whether participants had used any motion-related word to describe each image. For example, one image showed a road in the middle of a green area. If this image had been described by a motion-related word (e.g., the road *passes* through green lands), it was considered as an implied motion (imaginary movement of a point across an image as the source of implied motion). In one image, a running man on the field was shown (a moving object as the source of implied motion). In another image, traces of brushstrokes were shown (hand movement of image creator as the source of implied motion). If these images were described by motion-related words (e.g., a man is *running* on the field, someone has *moved* a brush on a paper, etc.), they were considered as implied motion in static images. It was assumed that using motion-related words to describe a static image was an indication that the image had created a sense of motion for the observer.

2.3 Data analysis

For each category of images, the percentage of cases in which the image had been described by motion-related words was calculated. Since four types of implied motion were examined in this study, four values were obtained. Each value could show the extent to which each category of implied motion created a sense of motion for participants of the study.

3. RESULTS

The results of the experiment have been given in Table 1.

These results indicate that all four types of implied motion could create a significant sense of motion for the observer. The strongest sense of motion was created by a moving object in a static image (96%). The weakest sense of motion was created by past experiences of the observer as the source of implied motion (61%). However, even this level of sense of motion could be significant. These results confirmed the hypothesis of the study. In the following section, these four types of implied motion are discussed separately.

4. DISCUSSION

Results obtained in this study suggested that implied motion may exist in a variety of ways in an image. The mechanisms that are involved in different kinds of implied motion may be different in some respects. The results indicated that there might be four kinds of implied motion in static images: a moving object as the source of implied motion, hand movements of the image creator as the source of implied motion, past experiences of the observer as the source of implied motion, and imaginary movement of a point across an image as the source of implied motion.

4.1 A moving object as the source of implied motion

Results of the experiment indicated that in 96% of cases, this type of static images creates a sense of motion in the observer. In this type of implied motion, a static image shows an object/person in the state of movement or an object/person that has the posture of movement in a certain direction. Since we are familiar with the ways

Table 1. Percentages of using motion words to describe images in the experiment

Type of implied motion (source of implied motion)	A moving object	Hand movements of image creator	Past experiences of the observer	Imaginary movement of a point
Percentage	96%	67%	61%	84%

that people and objects move, we can immediately realize whether an image shows a moving or a static event. Therefore, the static image of a moving person or object can easily create a sense of motion in the observer. As mentioned, most of the past studies have focused on this type of implied motion (e.g., Pavan et al., 2011; Williams & Wright, 2010). Although these images are static, they are directly related to motion events. The important point about this category of implied motion is that an element within the image inherently has the feature of movement. This is the main point that distinguishes this type of implied motion from other types of implied motion. In fact, this type of images directly shows a motion event, while other types of implied motion in static images indirectly show a motion event. This could explain why this type of implied motion creates the strongest sense of motion in the observer.

4.2 Hand movements of the image creator as the source of implied motion

Hand movements of the creator of an image can be the source of implied motion in that image. This is supported by the findings of those studies that have investigated the activation of the motor areas of the brain when an observer looks at abstract works of art (e.g., Cattaneo, Schiavi, Silvanto, & Nadal, 2017; Sbriscia-Fioretti et al., 2013; Thakral et al., 2012; Umilta' et al., 2012; Zhao et al., 2020). Results of these studies have suggested that premotor and motor cortical areas are activated when the observer looks at traces of brushstrokes in the abstract works of art. Therefore, it could be proposed that hand movements involved in the brushstrokes are simulated when the observer looks at traces of brush-strokes. Findings of these studies suggest that hand movements that have produced some parts of a painting may be simulated by the observer and thus be the cause of activation in premotor and motor areas of the brain.

One group of related studies has specifically focused on the activation of motor areas when an observer looks at handwritten or printed letters. Since handwritten and printed letters can be seen as one special type of image, it can be said that these studies are not inherently different from the studies that have been conducted on abstract works of art. Two studies have reported that observing static letters activates cortical motor areas (James & Gauthier 2006; Longcamp, Anton, Roth, & Velay, 2003). Longcamp, Hlushchuk, and Hari (2011) examined neural activities during observing handwritten letters vs. printed letters. They reported that viewing handwritten letters involves a stronger neural activation in left primary motor cortex and the supplementary motor area. Similar ideas about dynamic information in static images have been discussed in several other works (Babcock & Freyd, 1988; Freyd, 1983a; Freyd, 1983b; Futterweit, & Beilin, 1994). The implied motion that originates from hand movements of the creator of the image is more covert than the first type of implied motion, as it does not directly show the movement of an object. The interesting point is that some images have a strong degree of implied motion of this type. The trace of a rapid brushstroke that has a dark color in one side, and its color gradually fades as it goes toward the opposite side has a strong degree of implied motion. This image has a strong degree of implied motion as all of us have seen that rapid movement of a brush on a canvas creates such a trace. This is also the case with the trace of a pen on a paper. According to a theory presented by Leyton (1999), the shape of an object or an image could show us a history of its development; it could implicitly show us the processes of growth, pushing, stretching, resistance, and other processes that have shaped that object or image during a period of time. He offers a description of the processes through which people infer the causal history of objects' developments. A simulation of this historical development can be simulated in the mind of an observer who looks at the object of image. In fact, in the same way that the history of creating handwritten letters can be simulated in the mind of an observer, the developmental history of an object or an image can be simulated.

4.3 Past experiences of the observer as the source of implied motion

Past experiences of an individual can be an important source for implied motion in an image. Based on our past experiences, we know that some objects have some kind of association with movement, even though those objects may be inherently static. For example, road is inherently a static object. But, based on our past experiences, we know that it has a strong association with movement of other objects. That is why the process of observing a road may be the cause of activation in the motor areas of the brain. In fact, observing a road or the image of a road may activate those past experiences in which we have seen movement of objects on the roads. This kind of implied motion in the image is highly dependent on the past experiences of the individual. The strength of implied motion in such images may vary across individuals. In other words, an image may have a stronger degree of implied motion for an individual depending on her/his past experiences in dealing with the objects in that image. For example, the image of a road may have a stronger degree of implied motion for a driver who has spent a lot of time moving on the roads. The strength of implied motion of such an image may be significantly lower for a person who has never experienced moving on the roads. Hubbard (2005, 2018) lists several characteristics of the observer that could affect representational momentum, such as attention allocation, the tracking of visual stimulus, action plan activation, age, and pathology. If it is assumed that these characteristics affect visual perception in generally and implied motion perception specifically, we can add past experiences of the observer as one of the important factors that could affect the process of perceiving implied motion in a static image.

Another example could make the point clearer. In Figure 1, the graphical representation of the mathematical function $f(x)=Sin\ x$ has been shown. There are many oscillating movements that are similar to this graphical representation. The wave-like movement of a rope is one example. Since we have seen many movements like this in our past experiences, the process of observing the graphical representation of this function could activate those past experiences. Therefore, looking at this graphical representation may involve some degree of the motor system activation.

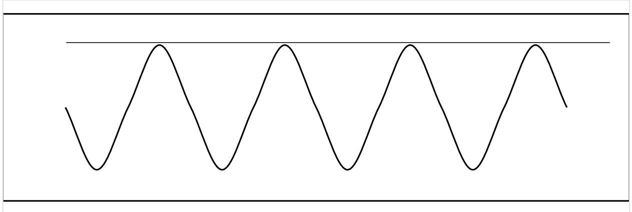

Figure 1. Graph of *f(x)=Sin x*

4.4 Imaginary movement of a point across an image as the source of implied motion

In our description of concepts, sometimes we use a spatially dynamic situation to describe a static concept. A fictive motion sentence attributes the feature of movement to an inherently static concept. Such metaphorical descriptions occur in many daily sentences in languages of the world, including English (Matlock, 2004, 2010; Langacker, 1999; Talmy, 1996), Japanese (Matsumoto, 1996), Spanish (Rojo & Valenzuela, 2003), Hindi (Mishra, 2009), and Danish (Wallentin, Lund, Østergaard, Østergaard, & Roepstorff, 2005). Talmy (1996) refers to this phenomenon as fictive motion, a cognitive mechanism through which a static entity is conceptualized in terms of a dynamic concept. The sentences "*The mountain range goes from west to east*" and "*The road runs through the desert*" are two examples of such sentences. Langacker (1986) refers to this description as abstract motion, and Matsumoto (1996) calls it subjective motion. Several behavioral and eye-tracking studies have found evidence that suggests understanding fictive motion sentences involves spatial processing (for a review, see Matlock, 2010). Findings of a neuroimaging study suggested that processing actual and fictive motion sentences involves the activation of MT+, a brain region that is selectively activated during motion perception (Saygin, McCullough, Alac, & Emmorey, 2010).

A question that is raised here is that what characteristics of an image play a role in considering it as a fictive motion. In other words, we want to know what characteristics an image should have to be perceived as a fictive motion. Hubbard (2005, 2018) mentions some characteristics of the target object and the surrounding context that could affect the process of perceiving its movement, such as velocity, direction, shape and size of the moving object, surface form of the moving object, the presence of a larger surrounding context, schematic information relevant to that context, the presence of a landmark, the presence of a distractor, and expectations regarding future motion of target. In addition to these factors that can be applied to perceiving real and fictive motions, there are some other factors that could specially affect the process of perceiving fictive motion. It is suggested that a change across an image that has the three key characteristics of being rule-based (clearly-defined), continuous, and gradual are critical in perceiving that image as a fictive motion. For example, when one part of an image has a darker color and it gradually and continuously becomes lighter as we move from that part to other parts in a certain direction, this change is perceived as a fictive motion. In fact, the gradual and continuous change that follows a clearly-defined organization is perceived as the fictive motion of an object across that image. To take another example, when one part of a line in an image has a larger width and it gradually and continuously becomes narrower as we scan from the wider part of the line to the narrower part of the line, this change is perceived as a fictive motion. In fact, the feature of being rule-based enables us to predict the shape of the image as we scan that image along a certain direction. When we scan a line that becomes narrower and narrower from left to right, this rule-based shape of the line enables us to predict its shape during the process of scanning. The predictability of the behavior of a moving object (such as velocity) and the predictability of the trace of its movement are important factors in how we perceive its movement. Findings of a study conducted by Getzmann and Lewald (2009) indicated that irregular or unpredictable velocity of a moving object reduces representational momentum (for a review, see Hubbard, 2019). The predictability of the trace of a fictive motion can also be a key factor in how we perceive that fictive motion. A straight line or a curve that is close to a straight line along its direction could induce a strong fictive motion, as its shape is predicable when the observer scans it along a certain direction. On the other hand, the unorderly shape of a curve could induce much weaker fictive motion.

It must be noted that perceiving a gradual, continuous, and rule-based change as a fictive motion may not be restricted to visuals. It might also be the case with auditory stimuli. When we hear a sound that gradually and continuously fades, this change may be perceived as the movement of an object. This is very similar to the fading sound of a car that passes by us and gradually and continuously goes away. When the sound source is a moving object relative to the hearer, the changes in the sound are perceived as a motion event. This is a real auditory motion. When the sound source is stationary relative to the hearer and the strength of sound changes in a rule-based or systematic manner, the changes in the sound are again perceived as a motion event. However, this is not a real auditory motion. It is a fictive auditory motion. It is fictive because the sound source does not move, but the hearer perceives it as a moving object. According to Carlile and Leung (2016), three factors are relevant to auditory motion: 1) whether the sound source is moving or stationary, 2) location and trajectory of the moving object, 3) speed of the moving object relative to the hearer. These three factors are critical in perceiving a sound as a motion event.

Any rule-based visual or auditory change that is gradual and continuous may be perceived as a motion event or a fictive motion. Therefore, the perception of a rule-based, gradual, and continuous change (visual or auditory change) could involve the activation of the motor system. In fact, any rule-based, gradual, and continuous change from strong to weak or from weak to strong can be perceived as a movement from one point to another point. Therefore, visual or auditory perception of a stimulus that undergoes a gradual and continuous change from strong to weak (or vice versa) can activate the motor system. Any gradual and continuous change from strong to weak (or vice versa) is metaphorically perceived (or understood) as a motion. From the perspective of the strong version of embodiment (Gallese & Lakoff, 2005), understanding such a metaphor involves the activation of the motor system.

5. GENERAL DISCUSSIONS

5.1 Real and metaphorical implied motion

The implied motion in an image may be real or metaphorical. Real implied motion originates from a real motion event. Among the four types of implied motion that were discussed, the first three types are real implied motions, while the fourth one is metaphorical. The first type of implied motion is an image that shows a moving object in a certain moment of its movement. Although the image is static, it captures a moment of a real motion event. The second type of implied motion is real in that the hand movements of image creator are simulated in the mind of the observer. Although the image itself does not directly show a motion event, it reflects those hand movements that have created that image. Therefore, this type of implied motion can be seen as a real implied motion. The third type of implied motion is also real, as it shows an object that has some kind of association with some real motion events. Observing the image of that object activates past experiences that involved those real motion events. Therefore, real motion events are simulated in the mind of the observer. However, the fourth type of implied motion does not reflect a real motion event, as the fictive movement of a point is the source of this type of implied motion. When it is said *the mountain range passes through the country*, no real movement takes place. Here, the source of movement is the imaginary movement of a point along the mountain range. Therefore, this type of implied motion is metaphorical.

5.2 Strength of implied motion

As mentioned, implied image may exist in several types in an image. There might be one or more than one types of implied motion in an image. The sum of implied motions in an image determines the strength of implied motion in that image. This means that some images may have a stronger degree of implied motion compared to other images. For example, a painting that depicts a track in a jungle may have three types of implied motion. Hand movements of the painter that depicts the track could be the first type of implied motion, as a track can be depicted by a single movement of the brush. Past experiences of the observer could be the second source of implied motion, as every track has an association with movements of the people. Fictive motion of a point along the image of the track could be the third source of implied motion. This type of implied motion even appears in linguistic metaphors such as *the track passes through the jungle*.

Strength of implied motion can be called degree of implied motor strength. Implied motor strength of an image is a subset of motor strength of that image. Motor strength of an image is the extent to which that image is associated with motion events or the extent to which observing that image activates the motor system of the observer. Degree of motor strength of an image or, more generally, degree of motor strength of a concept is closely related to perceptual and action strength of that concept. A number of studies have calculated perceptual strength of concepts in various modalities (e.g., Chen, Zhao, Long, Lu, & Huang, 2019; Filipović Đurđević, Popović Stijačić, & Karapandžić, 2016; Miklashevsky, 2018; Speed & Majid, 2017). Findings of these studies have demonstrated that perceptual strength of concepts in various modalities varies across a broad range. While some concepts have a very low degree of perceptual strength in a certain modality, others have a very high degree of perceptual strength in that modality. Between these two extreme points of perceptual strength, concepts may have a wide range of perceptual strength in various modalities. For example, the concept of "scream" has a strong degree of auditory strength, while the concept of "pencil" has a much weaker degree of auditory strength. To take another example, the concept of "car" has a strong degree of visual strength, while the concept of "friendship" has a weaker degree of visual strength. This can also be the case with degree of implied motion of images. In fact, strength of implied motion of an image could be highly related to the degree of action strength of that concept, as action and motion are strongly correlated.

6. CONCLUSION

Since pictures are static, they cannot directly show movements of objects. However, they can show movements in an implied manner. As mentioned, there are four types of implied motion in an image: a moving object as the source of implied motion, hand movements of the image creator as the source of implied motion, past experiences of the observer as the source of implied motion, and imaginary movement of a point across an image as the source of implied motion. An image may contain one or more than one of these implied motions. Degree of implied motor strength of an image depends on the sum of various types of implied motion. Therefore, degree of implied motor strength of images may vary across a wide range. Some images have a high degree of implied motor strength. On the other hand, some images may have a very low degree of implied motor strength. Finally, it must be noted that sometimes it is difficult to say which category of implied motion an image falls into.

For example, the image of a narrow track in a jungle appropriately falls into the second, third, and fourth categories of implied motion. In fact, the image of the track contains the three types of implied motion at the same time. Making a comparison between the neurological bases of various types of implied motion in static images is a question that can be investigated in future studies.

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