Parkinson's Disease Patients' Comprehension and Production of Co-Speech Gestures

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STATEMENT OF AUTHORSHIP

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ABSTRACT

Sensorimotor representations are essential to act goal-directed and take role in the way we perceive, comprehend, and produce actions as well as language containing actions. Due to the mobile feature of human beings, spatial details also accompany these representations and reflect on the linguistic statements explaining actions. Studies conducted with neurotypical participants suggest that both abstract and concrete actions simulate similar sensorimotor mechanism. Thus, spatial details provided in the linguistic statements of concrete actions are also valid for the expressions of abstract actions. Gestures can also ease the cognitive load of the linguistic statements expressing concrete and abstract actions. However, if the individual possesses a condition resulting in speech impairment such as Parkinson's Disease (PD), alterations may occur in the comprehension and production of co-speech gestures. The aim of this study was to expand our knowledge with respect to PD's effect on co-speech iconic gesture comprehension; and production for both concrete and abstract actions. We recruited 18 PD patients and age and education-matched 18 neurotypical controls. We introduced co-speech gesture comprehension and production tasks to reveal the underlying mechanism of these profiles. While the results on the comprehension task revealed significant differences for both action types between groups, the production task showed that PD did not affect the way patients use co-speech iconic gestures, except with the dynamic events referring to concrete actions (but not to abstract actions). Also, the correlational analysis between these two tasks revealed no association between co-speech comprehension and production mechanisms. These results suggest that PD may not be fully related to problems in gesture production. Yet, comprehension of co-speech gestures may be influenced by problems in conceptualization of actions.

Keyword: embodied cognition, co-speech gesture, action, Parkinson's Disease

ÖZET

Duyusal-motor temsiller amaca yönelik hareketlerin sergilenmesinde önem taşır ve hareketin yanı sıra hareket içeren ifadelerin algılanmasında, anlamlandırılmasında ve üretilmesinde rol alır. İnsanların hareketli doğasından dolayı bu temsiller uzamsal detaylar içerir ve hareket içeren sözlü ifadelere de bu detaylar yansır. Sağlıklı bireylerle yapılan çalışmalar hem soyut hem de somut hareketlerin benzer duyusal-motor mekanizmalarını simüle ettiğini ifade etmiştir. Bu nedenle, somut hareket ifadelerinin uzamsal detaylar içermesinin soyut hareket ifadeleri için de geçerli olabileceği öngörülmüştür. El jestleri de somut ve soyut hareket içeren sözlü kullanımların ifade edilmesinde bireyin bilişsel yükünü hafifletmektedir. Fakat bireyin Parkinson gibi konuşma bozukluğuna neden olan bir hastalığa sahip olması kişinin konuşmaya eşlik eden jestleri anlamlandırmasına ve üretmesine etkide bulunabilir. Bu çalışmanın amacı Parkinson hastalığının soyut ve somut hareket içeren sözlü ifadelere eşlik eden ikonik jestlerin anlamlandırılması ve üretilmesi üzerindeki etkisine bakmaktır. Çalışmaya 18 Parkinson hastası ve yaş-eğitim düzeyi eşleştirilmiş 18 sağlıklı birey katılmıştır. Katılımcılara konuşmaya eşlik eden jestlerin anlamlandırılması ve üretilmesi üzerine çalışmalar sunulmuştur. Anlamlandırma çalışmasının sonuçlarına göre her iki hareket türünde de sağlıklı bireyler ile hastalar arasında anlamlı fark bulunurken, üretim çalışmasının sonuçları hastalığın konuşmaya eşlik eden ikonik jestlerin, somut hareketlerin ifadesi dışında, üretime herhangi bir etkisinin olmadığını göstermiştir. Buna ek olarak, iki çalışma arasındaki korelasyonel analize göre konuşmaya eşlik eden jestlerin anlamlandırılması ve üretimi arasında bir bağlantı bulunamamıştır. Bu sonuçlar Parkinson hastalığının jest üretimini doğrudan etkilemediğini, fakat hastalığa bağlı olan hareket konseptindeki problemlerin konuşma esnasında kullanılan jestlerin anlamlandırılmasına etki edebileceğini ortaya koymuştur.

Anahtar kelime: bedenselleşmiş biliş, konuşmaya eşlik eden jest, Parkinson hastalığı

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INTRODUCTION

Perception is one of the major abilities of humans that enables a person to orient objects or events, and to execute goal-directed actions. The bidirectional interaction between action and perception contributes to the formation of sensorimotor experiences via integrating the sensory and motor input accumulated from the environment. In turn, this interaction supplies the opportunity to process the input and elicit actions accordingly in a very short period of time (for a review, see Hostetter & Alibali, 2008; Hostetter & Alibali, 2019). These sensorimotor experiences can emerge from visual and motor representations as the individual interacts with the world. Information acquired from the surrounding aids the expression of these interoceptive representations in linguistic statements or body movements (Casasanto & Lozano, 2007; Barsalou, 2008). In this study, we examine how Parkinson's Disease (PD), known as one of the movement disorders, affects the formation of sensorimotor representations and the possible consequences of disrupted representations in terms of co-speech gesture comprehension and production.

Action, Perception, and Mental Representations

There are ongoing discussions regarding the interaction between mind and the world (Wilson, 2002). While the stronger perspective of embodied cognition defends that the neural system of our brain is devoted majorly to the sensorimotor processing, weaker perspective of embodied cognition claims that cognition is grounded in sensorimotor representations, and it has various extensions such as simulations, situated actions, and bodily states (for review see Borghi & Cimatti, 2010). The proponents of the weaker view suggest that even if the mind does not have a direct interaction with the physical world, it can still have a grounded activity due to the sensory and motor processes' interactions with the previously formed mental representations (Borghi & Cimatti, 2010; Garbarini & Adenzato, 2004; Barsalou, 2008). Despite different points of view, the main tenet of both perspectives is that conceptual knowledge is based on the input-output mechanism, and this mechanism endeavors the bidirectional interaction between body and physical environment (Kemmerer, Miller, MacPherson, Huber, & Tranel, 2013). In this paper, the focus will be on *action,* which is one of the domains of Embodied Cognition Theory (ECT) that helps us understand cognitive processes. We take the perspective of the weaker view of embodied cognition and suggest that representations are used to comprehend and produce actions, in addition to the language associated with actions that are either present or not in the concurrent environment.

In a broader sense, ECT indicates that human cognition is rooted in the sensorimotor experiences as we interact with the world. This interaction enables us to form sensorimotor representations, which is useful in comprehending and producing actions (Shapiro, 2014; Wilson, 2002). Moreover, the theory goes beyond this explanation and points out that these sensorimotor representations are used to produce and comprehend linguistic statements associated with actions even when the overt action is not perceptually present in the concurrent environment (Wilson, 2002). Based on the embodied cognition framework, Hostetter and Alibali (2008) claim that there is a contingency between the perceptual and motor representations, which is essential to generate and give meaning to the action (see also Hostetter & Alibali, 2019).

Studies on action-related language provide substantial evidence for this claim with concrete as well as abstract linguistic statements (Boroditsky & Ramscar, 2002; Borreggine & Kaschak, 2006; Glenberg & Kaschak, 2002; Richardson, Spivey, Barsalou, & McRae, 2003; Santana & de Vega, 2011). For instance, Glenberg and Kaschak (2002) conducted an experiment that assessed the sensibility of sentences transferring concrete and abstract objects towards and away from the body. In half of the sentences, the objects were transferred towards the reader (e.g., Andy delivered the *pizza* to you), and in the other half, the objects were transferred away from the reader (e.g., you told the *story* to her). Prior to reading the target sentences, a three-button box, aligned according to front-back axis, was replaced on the lap of the reader. In one of the conditions, pressing the front button was consistent with transferring the object away from the reader, whereas the other condition was organized in the opposite direction. Readers who read sentences involving actions consistent with the arm movement direction made their judgements quicker, whereas inconsistent actions took more time to make decisions with no significant difference between concrete and abstract objects. Similarly, Santana and de Vega (2011) conducted an experiment with verbs that involve concrete and abstract actions. Participants who read concrete action sentences (e.g. she *climbed* up the hill) or abstract action sentences (e.g., she *climbed* up in the company) had difficulties in moving their hands up and down while reading sentences that do not match with their hand movement direction. Neurophysiological assessments confirmed the behavioral data, indicating that in both concrete (Hauk, Johnsrude, & Pulvermüller, 2004; Jirak, Menz, Buccino, Borghi, & Binkofski, 2010; Pulvermüller, 2005; Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005; Willems & Hagoort, 2007) and abstract (Glenberg, Sato, Cattaneo, Riggio, Palumbo, & Buccino, 2008) language comprehension, the motor-related areas were evoked with the corresponding action verbs.

Sensorimotor representations can coexist with spatial details. In particular, to execute or comprehend an action, one needs to identify two reference points that are related to each other in space so that one can act in a goal-directed manner (for a review, see Paillard, 1991; Philipona, O'Regan, & Nadal, 2003). This relation between sensorimotor processing and spatial information is also used in the expression and comprehension of linguistic statements related to action (Barsalou, 2008; Richardson, Spivey, Edelman, & Naples, 2001). For instance, concrete actions can be expressed in a sentence such as "the child is climbing up to the tree." However, not only the sensorimotor representations of concrete actions are expressed with the help of spatial information. That is, we also use action expressions of spatial information in metaphoric expressions, relying on the physical world via rich and experience-based analogies (e.g., Lakoff & Johnson, 1999; Gibbs, Bogdanovich, Sykes, & Barr, 1997; Richardson et al., 2001; Casasanto & Lozano, 2007). For example, sentences such as "The road runs along the coast" or "She grasped the idea" do not have any physical evidence. However, these sentences still present the sense of action to the listener/speaker by benefiting from the spatial information used in concrete actions (Matlock, 2004; Desai, Binder, Conant, Mano, & Seidenberg, 2011). Talmy (2000) explains this phenomenon in terms of mental simulations. People mentally simulate motor and visual representations by taking perspective in the scene along with the figure and conceptualize the abstract action via focusing on spatial details from their imagined spatial scene based on their existing representations. In an experiment, Richardson and his colleagues (2001) inquired whether participants have an agreement on the spatial components of the verbs by comparing the concreteness levels such as lifted, pushed (i.e., highly concrete) versus offended, respected (i.e. lowly concrete) in a forced choice task and in an open-ended task. In the forced choice task, they asked the participants to choose one of the images in the boxes that explained the verb provided in the best way. In the latter task, they asked participants to create their own spatial schemas with the provided images. The results showed that, in both tasks, there was an agreement among participants in terms of their spatial representation regardless of the concreteness levels of the action verbs. Likewise, Matlock (2006) conducted an experiment in which the participants were provided sentences involving abstract actions with different manners (e.g., the road *zigzags up* the hill vs the highway *races over* the railroad tracks). Then, they were asked to draw lines, indicating the representation of their trajectory understanding. The results showed that abstract actions indicating faster manners correlated with long, thin, and straight lines, while slow-manner lines had the contrasting characteristics (see also Matlock & Richardson, 2004; Richardson et al., 2003). These findings suggest similar expressions of concrete and abstract actions in linguistic statements, since they have a common platform in which both concrete and abstract actions' representations use the similar spatial details replaced in the concrete or imagined scene as Talmy (2000) proposed.

Knowing the role of sensorimotor and spatial representations in comprehending and producing actions is important to examine how PD affects the formation of these representations. Additionally, how these representations are employed during comprehension and expression of different action verbs (i.e., concrete and abstract actions) with spatial details provide the basis to understand the possible outcomes of disrupted representations PD can cause, and how these outcomes reflect on the communication skills of PD patients such as gestures occurring during speech. In this part of the paper, we shift our focus on co-speech gestures that reflect strongly the content of the speaker's speech or thought (Kita, Alibali, & Chu, 2017).

Mental Representations and Co-Speech Gestures

Co-speech hand gestures are a way of expressing concrete and abstract actions. In this study, we specifically focus on *representational gestures* that people use frequently during their spontaneous speech. These gestures are hand movements representing the information (e.g., action, object, trajectory) related to the content of the concurrent speech (Cartmill, Beilock, & Goldin-Meadow, 2012; Kita et al., 2017). Several views explain what representational gestures serve for. One of these views is the Interface Model proposed by Kita and Özyürek (2003). In their model, they state that representational gestures are an output of spatio-motoric representations that can be considered as an interface among space, action-related thoughts, and speech. In other words, gestures provide information for spatio-motoric features of the referent and arrange this information. As a result, gestures can be expressed properly during speech (for review, see Alibali, 2005). Gestures can be categorized in different ways. *Iconic gestures* are the hand movements presenting a concrete referent (e.g., object, event) with the movement or the shape of the hand, and *metaphoric gestures*, on the other hand, are the abstract ideas shown as a concrete referent despite the absence of concrete information in the surrounding (McNeill, 1992). For example, making a fist and pointing out only the thumb and the pinkie finger to illustrate a "phone" (i.e., concrete gesture) or holding two hands facing up to emphasize "equality" (i.e., metaphoric gesture). Moreover, the Lexical Retrieval Hypothesis states that via gesturing, people recall words embodied with spatial features easier, and this decreases the cognitive load of the speaker during a conversation (Krauss, Chen, & Gottesman, 2000). In common, these perspectives indicate that gestures have a close relation with spatio-motoric information. The question is, how does spatio-motoric information get into the picture?

Hostetter and Alibali (2008) came up with the Gesture-as-Simulated-Action (GSA) framework to explain how gestures containing spatio-motoric information originate (see also Hostetter & Alibali, 2019). Going along with the ECT, the GSA framework suggests that motor and perceptual representations are in the center of the linguistic processes and gesture production. Imagining, planning, and articulating an action that involves both perceptual and motor simulations, activates the motor-related areas associated with encoding events. Usually, these simulations are suppressed. Yet, if these simulations are strong enough, the neural system associated with cortical motor activities cause them to be an overt action. Since there is a common mechanism recruited in this process, they propose that a domino effect occurs in which simulation emerging from one end (i.e., language processes) also spills over to the other end (i.e., gesture production). In this context, while someone is speaking about an action of running, the motor-related areas will be simulated by the representations associated with running behavior, and once this simulation hits the threshold, gesturing behavior occurs.

Empirical studies confirmed that representational gestures frequently occur when the content of the speech contains spatial information (e.g., Casasanto and Lozano, 2007; Hostetter, Alibali, & Kita, 2007; Krauss, 1998; Özer et al., 2017). That is both iconic and metaphoric co-speech gestures, in a way, reflect the spatial cognitive activity of the individual (for reviews, see Alibali, 2005; Kita, 2000). In Turkish, for instance, a person who is talking about "kids sliding down the slide (i.e., çocuklar kaydıraktan *kayıyorlar*)" can use a straight hand going downwards diagonally to represent the referent (i.e., kids), the path (i.e., downwards) and the manner (i.e., sliding). Regarding the metaphoric gestures, a person saying, "they *suppressed* the smell with perfume (i.e., kokuyu parfüm ile *bastırdı*)," one will make a palm down gesture moving up and down to represent the referent (i.e., smell), the path (i.e., downwards) and the action (i.e., suppress). To find out the underlying mechanism between spatial and sensorimotor representations, Casasanto and Lozano (2007) asked participants to read and retell brief stories that include Literal Spatial Language (e.g., my rocket went high), Metaphoric Spatial Language (e.g., my grades went high), and Non-Spatial Language (e.g., my grades got better). They were interested in whether speech with literal and metaphorical spatial content would be disrupted in the case of being prevented from gesturing via marble movement task that occupies participant's motor ability. The results showed that the marble task interfered not only the fluency of stories involving spatial content, but also telling stories with spatial content intervened with the marble movement performance. In another study, Hostetter, Alibali, and Kita (2007) prevented participants from gesturing while they explained how to accomplish tasks that require motor information. When the content was related to spatio-motoric actions, the participants used fewer spatio-motoric details in their speech as well as more connectors like "and" compared to the gesture allowed condition. These findings provide the basis to propose that regardless of the concreteness level, speech containing spatial and motor information can be affected in a negative way if the person is restricted from gesturing.

The other aspect of co-speech gesture is how individuals interpret, in other words, comprehend the hand movements of another person in a spoken message. Co-speech gestures are highly dependent on the context of the speech, meaning that to comprehend co-speech gestures, it is essential to know the content of the discourse (Krauss, Morrel Samuels, & Colasante, 1991). Even though there is no extensive theory explaining the underlying mechanism of co-speech gesture comprehension, gesture-speech integration studies shed light on the mechanism of co-speech gesture comprehension (Kelly, Healey, Özyürek, & Holler, 2015; Kelly, Kravitz, & Hopkins, 2004; Kelly, Özyürek, & Maris, 2010; Özyürek, Willems, Kita, & Hagoort, 2007; Willems & Hagoort, 2007). The main argument of these studies is that, as the production of gesture-speech integration is highly associated with the language processes (Kita & Özyürek, 2003; McNeill, 2005), comprehending speech and gesture together should also be related to the same mechanism (Kelly et al., 2004; Kelly et al., 2010; Özyürek et al., 2007; Willems & Hagoort, 2007). On this matter, Kelly and his colleagues (2010) introduced the *Integrated-System Hypothesis* explaining the "mutual" and "obligatory" interaction of bimodal speech integration. In their study, by using matching (e.g., gesturing *chop*) and mismatching (e.g., gesturing *twist*) iconic gestures for the actions expressed verbally (e.g., saying *chop*), they found that gestures congruent with the verbal expression of the action induced fewer errors in short time as compare to mismatched actions. Thus, when the information in gesture and speech refers to the same actions, the semantic information is comprehended faster and accurately, whereas when the information in gesture and speech contradicts, the unified system constituted by two modalities break down (see also Özer & Göksun, under review).

Additionally, in a functional magnetic resonance imaging (fMRI) study, Özyürek et al. (2007) investigated which brain regions are involved in semantic comprehension when speech and iconic gestures together convey action information. Here, the focus was on additive information provided by the gesture, which did not exist in the spoken message and was congruent or incongruent with content of the previous sentence. The findings showed that when the additive information was given by iconic gestures, regardless of the congruency, semantic load activates regions associated with Broca's area, which is involved in both language and motor processes. In addition to Broca's area, increased activation in the premotor and motor areas was also observed, supporting the claim that both language and action sites are involved during gesture and speech integration. As mentioned earlier, regardless of the concreteness level, if linguistic expressions containing action verbs activate the motor-related areas (Glenberg, et al., 2008; Jirak et al., 2010; Pulvermüller et al., 2005), then, it is possible to observe an activation in motor-related areas while an individual is comprehending a metaphoric gesture accompanied by speech, in a similar fashion as in iconic gesture-speech comprehension. Kircher et al. (2009) carried out an experiment investigating the regions activated when abstract concepts' expressions in linguistic terms (e.g., spiritual bond) were accompanied by metaphoric gestures versus when both modalities were used in an isolated form. Based on their findings, integrated speech and metaphoric gestures reduced regions' activity that is related to semantic processing, possibly due to the reduced demand to understand the semantic meaning of the discourse. However, increased activity was found in regions associated with motor and linguistic processes compared to isolated conditions (see also Cornejo et al., 2009).

Overall, these studies provide evidence for the contribution of gestures to semantic comprehension. However, most of the previous studies focusing on this issue mainly employ the integration of speech and gesture modalities to explain the unified system (except the study conducted by Demir-Lira, Asaridou, Beharelle, Holt, Goldin-Meadow, and Small (2018) with children). Apart from the integration of verbal and gestural modalities, some studies focused on pantomime (Buccino et al., 2001; Grèzes, Armony, Rowe, & Passingham, 2003; Xu et al., 2009) and emblems (Xu et al., 2009; Andric et al., 2013). These gesture types can not necessarily stand alone independent from speech content; thus, do not provide information to understand the comprehension of iconic and metaphoric co-speech gestures (for review, see Yang, Andric, & Mathew, 2015).

In sum, knowing the underlying mechanism of producing and comprehending co-speech gestures that explain abstract and concrete concepts is important to question how specific populations who have speech impairment communicate in daily life. Do they produce gestures more than neurotypical individuals to explain abstract or concrete actions *or* does the impairment of speech affect the way they produce gestures? Does the inability to articulate these actions also cause them to have problems in understanding others' verbal and non-verbal messages related to actions? If so, at which level does comprehension problems occur? In the following section, these groups will be discussed to further our knowledge about the impact of the speech impairment on co-speech gesture production and comprehension.

Speech Impairment and Representational Co-Speech Gestures

Co-speech gestures mostly serve the person to communicate their ideas or thoughts more efficiently than gesture-free speech (Holler & Beattie, 2003; Hostetter, 2011). However, if one possesses speech impairment, then, it is possible to say that one will also have a high chance to experience difficulties in delivering their messages, especially the ones with spatial content. These individuals' nonverbal communications as in gesture use may be intact. Previous research suggests that this can be the case. People having speech impairments can compensate their spoken message using co-speech gestures (e.g., Akhavan, Göksun, & Nozari, 2018; Göksun, Lehet, Malykhina, & Chatterjee, 2015; Iverson & Braddock, 2011; Kita & Lausberg, 2008; Kong, Law, Wat, & Lai, 2015; Özer, Göksun, & Chatterjee, in press; Sekine & Rose, 2013). For instance, Göksun and her colleagues (2015) showed that individuals with left hemisphere damage (LHD) had more problems expressing the action events such as climbing up a tree compared to individuals with right hemisphere damage (RHD) or neurotypical controls. However, individuals with the LHD used more gestures containing spatial components compared to the individuals with the RHD and control groups. These results support the Interface Model (Kita & Özyürek, 2003), which suggests that speech and gesture stems from the same root in the brain but not overlapping entirely. In this case, findings of this study can be interpreted as, gestures can be a compensatory mechanism for the incapability of expressing spatio-motoric information with linguistic statements. Another study conducted with patients with aphasia who experience long-term speech impairment due to stroke (Ali, Lyden, & Brady, 2015) reported that patients with Broca's aphasia produced increased number of iconic gestures in speech related to concrete images or actions, whereas patients with Wernicke's aphasia used more metaphoric gestures to explain abstract concepts (Sekine & Rose, 2013).

Even if studies dwelling on co-speech gesture comprehension are not as much as production studies are, some empirical findings were conducted with patients with aphasia or apraxia, in which patients have difficulty in performing limbic movements (Pazzaglia, Smania, Corato, & Aglioti, 2008). For instance, Cocks, Sautin, Kita, Morgan, and Zlotowitz (2009) worked on a patient with Broca's aphasia to investigate whether the patient can integrate the information stemming from iconic co-speech gestures with the speech. The results showed that, compare to the control group, the patient with aphasia relied more on gestures during speech to decode the message, but still showed a low performance on semantic comprehension task. In an earlier study, Rothi, Heilman, and Watson (1985) compared patients with aphasia who had ideomotor apraxia to non-apraxic aphasic patients by using a pantomime-picture matching task. In ideomotor apraxia, patients' brain regions associated with the perceptuo-motoric areas were disrupted and they could not relate movements within space. Thus, they had difficulties in discriminating and attributing meanings to the hand gestures of others (Pazzaglia et al., 2008). In line with this information, Rothi et al. (1985) found that the aphasic patients with apraxia scored lower in the matching task and had longer reaction times than the non-apraxic patients and the control group.

Based on the findings of speech impairment groups, there are two points to be considered in the scope of this study. First, if an individual has a speech impairment but can produce co-speech gestures related to actions, then, language and gestures can be originated from the same mechanism, but function separately as suggested by the Interface Model (see Göksun et al., 2015; Sekine & Rose, 2013). Second, if an individual who has merely a speech impairment can read the meaning of the hand gestures (see Cocks et al., 2009), but a person with both speech and motor impairment cannot, then, motor problems may take relatively more role in the inability to understand the meaning of the hand movements than the speech impairment (see Rothi et al., 1985). However, these studies are not sufficient to support this argument since none of them address gesture production and comprehension together in a coverbal context. Additionally, not all of them provide information regarding abstract and concrete actions, thus, we cannot claim that both iconic and metaphoric gestures will be affected in the same way. In the next section, we will disclose the current literature addressing co-speech gesture production in patients with PD who have both motor and speech problems (Cleary, Poliakoff, Galpin, Dick, & Holler, 2011).

Parkinson's Disease and Representational Co-Speech Gesture

Parkinson's Disease (PD) is a multicentric neurodegenerative movement disorder thought to be caused by the depletion of dopaminergic activity in the nigrostriatal pathway due to the atrophy of dopaminergic cells (Bartels & Leenders, 2009; Cleary et al., 2011). Typically, this pathway contains projection starting from substantia nigra to the subcortical areas of basal ganglia that plays a major role in voluntary movement with the involvement of dopaminergic activity. With the development of PD, dopaminergic cell loss occurs in substantia nigra and abnormalities emerge in the basal ganglia neurons responsible for sensorimotor responses (Lang & Lozano, 1998). The damage in multiple areas of the brain has differential effects on patients' lives resulting in motor problems such as tremors, rigidity, gait abnormalities, akinesia (Bartels & Leenders, 2009; Kemmerer et al., 2013), as well as non-motor problems affecting cognitive and emotional functions such as the inability to perform goal-directed action, episodic memory problems, visuospatial dysfunction, sleep disturbances, depression, anxiety (see Bartels & Leenders, 2009; Williams-Gray, Foltynie, Lewis, & Barker, 2006). Another influence of PD on patients' lives is the problems related to communicative abilities due to motor deficits such as *speech impairment and gesture impairment* (Williams-Gray, Foltynie, Brayne, Robbins & Barker, 2007; Bartels & Leenders, 2009; Cleary et al., 2011; Bocanegra et al., 2015). Since communicative abilities have a great impact on the patient's quality of life, speech and/or gesture impairments became one of the novel topics investigated in PD literature. The aim of this study is to further our knowledge in this regard and ask how impaired sensorimotor abilities in PD affect co-speech gesture comprehension and gesture production that contains spatio-motoric information such as concrete and abstract actions.

As mentioned earlier, ECT framework suggests that an individual forms sensorimotor representation via interacting with the outside world, and then, make use out of the formed representation to comprehend and produce further actions (Wilson, 2002). In this case, we will expect to see PD patients having difficulties in comprehending and producing actions, in addition to action related language as a result of their motor impairment. Related to this prediction, Kloeters et al. (2016) conducted an experiment with PD patients to evaluate if motoric problems in PD had affected their movement perception in addition to execution while they were off medication. They found lower recognition rates of human movements in PD than neurotypical controls. They also emphasized that actions including objects and goal-directed actions (e.g., kick a soccer ball, throwing an object) could widen the difference between these two groups in which PD patients have more challenging times in perceiving and comprehending shown movements (Jaywant, Shiffrar, Roy, & Cronin-Golomb, 2016). Additionally, Poliakoff (2013) emphasizes that neurotypical individuals' motor system is activated when they see action-related words. Therefore, if a person has an impairment in the motor related areas, we may also observe problems in action-related words (e.g., Cotelli et al., 2007; Boulenger et al., 2008; Rodríguez-Ferreiro, Menéndez, Ribacoba, & Cuetos, 2009; Herrera, Rodriguez-Ferreiro, & Cuetos, 2012; Fernandino et al., 2013; Kemmerer et al., 2013; Bocanegra et al., 2015). For example, Herrera, Rodriguez-Ferreiro, and Cuetos (2012) found that in action-related words that included complicated actions such as digging behavior, PD patients made more errors in naming these actions compared to less complicated or canonical actions such as sleeping. Yet, Kemmerer et al. (2013) provided slightly different results than the previous findings. They asked whether PD impacted semantic judgement of different action verbs such as running, hitting, speaking, cutting compared to non-action verbs. They found no significant difference in terms of the accuracy in judging similar action related words between neurotypical control group and PD patient group. However, PD patients' response times were significantly slower to both action words and non-action verbs than controls, meaning that even if the motor problem did not affect the comprehension of the verbs, the time to process the semantic meaning was different for two groups.

Apart from the effects of PD on linguistic output, a few studies examined the alterations in co-speech gesture production (Humphries, Holler, Crawford, Herrera, & Poliakoff, 2016; Cleary et al., 2011). For instance, Humphries et al. (2016) investigated whether PD affected the amount and the type of the gestures employed, in addition to whether PD influenced the perspective of the patients' gesturing behavior that occurred in action-related speech. They found that the amount of gesture use did not differ between PD and age-matched control group; yet, the viewpoints taken by the groups were different. While age-matched group used a character viewpoint (i.e., from a first-person perspective), PD group used an observer viewpoint (i.e., from a third-person perspective), suggesting that even though the motor impairment did not affect the amount of the gesture production, the way a gesture is employed by the patients could differ. Based on the ECT framework, it is possible that PD patients' mental representations regarding dynamic events may have altered. They added that there was no significant difference between the gesture types used among two groups. However, the authors stated that the findings in this study might be different if the study was conducted with patients who have more severe motor impairments. In another study, Cleary et al. (2011) addressed co-speech gesture properties of PD patients, investigating if on-medication PD patients have gesture production problems compared to controls and whether they had problems producing certain type of gestures. No significant difference was found between two groups in their overall gesture production. However, PD patients produced fewer and less informative iconic gestures associated with concrete actions compared to controls. The authors attributed the latter finding to the distorted spatio-motoric representations underlying gestures because of the motor impairments seen in PD.

Taken together, only a few studies have investigated co-speech gesture production in PD patients. Contrary to the common assumption, these studies demonstrate that PD patients can produce gestures related to dynamic events and this capability also enables them to have lexical access much easier, especially with the words that have spatial content (Beattie & Coughlan, 1999). Nevertheless, the limited literature on PD and co-speech gesture use mainly focuses on the concrete actions. It is not known if the patient can gesture a sentence such as "The lady jumped directly to the conclusion" during speech. If the action accompanied with an abstract concept (e.g., *jumping to* the conclusion) simulates the similar spatio-motoric representations as concrete actions do, then, there should not be any difference in the usage of metaphoric gestures when talking about abstract actions. Moreover, research has not examined how PD affects the comprehension of iconic and metaphoric co-speech gestures. Only a few studies investigated gesture perception and comprehension (Jaywant, Wasserman, Kemppainen, Neargarder, & Cronin-Golomb, 2016; Lotze et al., 2009). For instance, Jaywant et al. (2016) inquired if PD patients can discriminate and describe communicative (i.e., intransitive, social gestures such as waving hello) and non-communicative (e.g., transitive, object-oriented gestures such as brushing teeth) gestures with point-light stimuli. They report that PD patients significantly differed from the control group in terms of perceiving and describing non-communicative gestures compared to communicative gestures. Additionally, Lotze et al. (2009) found that PD patients could not identify emotional gestures as much as healthy participants could. Despite investigating different domains of gesturing behavior, these studies support the idea that PD influences the way we comprehend gestures. Nevertheless, we still do not know if PD will induce the same effect on speech accompanying gestures explaining abstract or concrete actions.

In this study, our aim is to address the gaps in the previous studies and extend our knowledge on how PD patients produce and comprehend iconic and metaphoric co-speech gestures for dynamic events. However, from now on, we will define metaphorical gestures as a subcategory of iconic gestures since they share the same properties except that metaphorical gestures refer to abstract concepts while iconic gestures refer to concrete concepts (Kita, 2014). Instead of using metaphorical gestures, we will make the distinction by describing iconic gestures representing concrete and abstract concepts. More specifically, since our focus is on how motor impairment influences the employment and interpretation of co-speech gestures referring to dynamic events, we will use the term as iconic gestures representing concrete and abstract *actions*. As the Integrated-System Hypothesis (Kelly et al., 2010) suggests, the underlying system of gesture-speech production can also tell us something about gesture-speech comprehension since there is a bidirectional effect between these two mechanisms. Thus, we formed our hypothesis related to co-speech gesture comprehension intertwined with the hypothesis of co-speech gesture production based on the Integrated-System Hypothesis (Kelly et al., 2010) and the Interface Model (Kita & Özyürek, 2003). If PD patients perceive both concrete and abstract actions in the same way, having problems in speech in terms of describing these actions may affect the linguistic output while explaining spatio-motoric details, but not the use of iconic gestures explaining concrete and abstract actions. That is, on medication patients may use iconic gestures representing both action types to compensate for their poor descriptions verbally. In this case, we predicted that patients would produce more co-speech iconic gestures representing concrete and abstract actions compared to neurotypical controls. However, if PD patients' general movement problems influenced their conceptualization of action, we would expect fewer iconic gestures depicting both action types during speech in PD group compared to neurotypical controls. Patients' medication might also influence the amount of beat gestures they use since beat gestures ease speech production (Lucero, Zaharchuk, & Casasanto, 2014). With neurotypical participants, Beattie and Coughlan (1999) found that beat gestures were used as much as iconic gestures during the resolution of tip-of-tongue phenomenon. Similarly, if medication normalizes patients' ability to move their hands freely, we would also expect PD patients to use beat gestures as much as neurotypical participants under medication.

In terms of gesture comprehension, taking the studies of Kloeters et al. (2016) and Jaywant et al. (2016) into account, if PD patients have a problem at the conceptual level meaning that if they cannot read the gesture as an action, then, we would expect to see low accuracy rates for PD patients in the gesture comprehension task for both concrete and abstract actions. However, if PD patients can read the gestures' meaning even in a longer duration compared to controls (Kemmerer et al., 2013), then, we would expect to see no difference between two groups in terms of the accuracy rates for both action types. There was also a possibility that producing and comprehending co-speech gestures are two separate mechanisms that do not affect each other. In other words, there might be a dissociation between these two profiles, in which finding a problem in producing co-speech gestures may not influence the performance on co-speech gesture comprehension, or vice versa. To test our hypotheses, we proposed an experiment consisting of a co-speech gesture comprehension and reproduction tasks conducted with on-medicated PD patients.

METHOD

Participants

We recruited 20 patients (M_{age}= 56,50, SD_{age}= 8,16, 14 males, 6 females) diagnosed with idiopathic PD from the Neurology Department of Koç University Hospital. However, two patients were left-handed and were excluded from the study. We screened all patients for dementia and included only the patients with mild to moderate severity of PD according to the Hoehn and Yahr Scale ($M_{H\&Y}$ = 2.09, $SD_{H\&Y}$ = 0.50) into the study by referring to the consultation of a neurologist ($M_{diagnoses}$ = 5.36 years, SD= 3.51). All PD patients were on dopaminergic medication (M_{LED} = 634.80 mg, SD= 340.25) at the time of the testing. We did not include patients who had visual or auditory impairments, or neurological disease other than PD. Additionally, all patients were interviewed by a psychiatrist before testing, and patients with depression were screened. For the neurotypical control group, we recruited 18 age- and education-matched (M_{age}= 56,61, SD_{age}= 8,88, 14 males, 4 females), right-handed neurologically healthy adults. All participants were native Turkish speakers. They were compensated with the travel expenses and lunch for their participation. To participate to the study, all participants gave their written consent that was based on the guidelines of Koç University IRB ethical committee in the beginning of the experiment.

Tasks and Stimuli

Neuropsychological Tests

To screen dementia and to assess executive functions, we administered the *Standardized Mini Mental State Exam Test (MMSE)* that consists of 30 items with 11 different cognitive tasks related to attention, memory, orientation, registration, and language (Folstein, Folstein, & McHugh, 1975). To rule out depression, we gave *Beck Depression Inventory* (BDI) that consisted of 21 items tapping on different psychological domains such as mood, sense of failure, guilt as well as somatic issues such as sleeping problems, libido and weight changes (Beck, Steer, & Carbin, 1988). To evaluate the anxiety level, we administered the *Beck Anxiety Inventory* (BAI) to the participants. Overall, there were 21 items in which 12 of them focused on somatic symptoms of anxiety and 9 items dwelled on subjective feeling of anxiety (Osman, Kopper, Barrios, Osman, & Wade, 1997). Additionally, the *Cognitive Failures Questionnaire* (CFQ) was administered to assure whether the participants can carry on their daily lives without having lapses in several areas such as perception memory and motor function (Broadbent, Cooper, FitzGerald, & Parkes, 1982).

We ran a subtest of Standardized University of Pennsylvania Computerized Neuropsychological Test Battery (UPennCNP) called the *Motor Praxis Task (MPraxis)* that assesses if the patient can make goal-directed movements by clicking on shrinking green squares on the screen with a mouse (Neves et al., 2014). Their reaction times were recorded. Additionally, we administered another subtest of UPennCNP called the *Letter-N-Back* to assure participants' working memory abilities were intact. In this task, there are three conditions named 0-back, 1-back and 2-back. In 0-back condition, participants pressed on the spacebar each time they saw an "X" letter on the screen. In 1-back condition, participants gave response when identical letters appeared on the screen one after the other. In 2-back condition, participants gave response when the same letters appeared on the screen going two trials back (Moore, Reise, Gur, Hakonarson, & Gur, 2015).

We used the *Gülhane Aphasia Test-II* (GAT) to evaluate whether participants have any language or speech disorders (Maviş, Colay, Topbaş & Tanrıdağ, 2007) by testing the speech fluency, auditory, and reading comprehension as well naming objects and oral repetition (Yavuzer, Güzelküçük, Küçükdeveci, & Ergin, 2001). We also applied the shortened version of the *Boston Naming Test* to evaluate their object naming abilities (Mack, Freed, Williams & Henderson, 1992). Participants saw 30 objects one by one and named those objects. Since there are no standardized tasks assessing action naming abilities in Turkish, we took 60 pictures randomly from the dataset of *Center for Research in Language-International Picture Naming Project Corpus CRL-IPNP* that has been normed across seven different languages (Bates et al., 2000). We asked another group of participants (N=30) to name the actions in Turkish and rate how much the picture reflects the action on a scale scored from 1 (low) to 5 (high). Thirty-one pictures that were highly rated (i.e., above 4) and named in the same way by different participants were selected and presented as an *Action Naming Test* (see Appendix A).

Experimental Tasks

Co-speech Gesture Production Task. We first prepared eight stories. Each story included three concrete and three abstract action verbs. We presented each sentence one by one on Qualtrics survey to 15 participants from Koç University and asked them to rate the action verbs based on their concreteness level within the context of the sentence. We selected the action verbs based on the ratings of the concreteness scale in which 1 was the lowest (i.e., abstract action) and 7 was the highest (i.e., concrete action) concreteness level. Verbs that the majority agreed on remained in the story, whereas the ones with an average of 3 to 5 were replaced with another action verb that was evaluated as high in concreteness level. After validating each verb, we tested the stories with a different group of individuals. In front of the camera, we asked 8 participants from Koç University to first read each story and then retell the stories to another person sitting against them. Based on the recordings, the stories that were most eligible to produce co-speech gestures were used in the actual experiment. As a result of all these pilot tests we ended up with 4 stories (see Appendix B for all stories).

Co-speech Gesture Comprehension Task. In this task, we identified 30 verbs fitting to both concrete and abstract action (e.g., *raise*) expressions in Turkish and can be expressed with the same gesture during a speech (see Appendices C and D). We constructed sentences involving these action verbs and replaced the action verbs with a nonsense (e.g., *novel*) word. We recorded a person telling the sentence with two different gestures that implied the same action verb in each category. Then, via Qualtrics, we asked people (N=13) to choose the most understandable gestures and gestures that could match with the verb. We prepared the task based on the most correctly answered 20 video clips for both action categories. In this task, we wanted the participant to assess what could be replaced with the nonsense word by observing the hand movements. Therefore, we displayed three alternative action verbs in the options. Among these options, one was the target action verb, one was another verb from the list that was a correct answer for another videoclip, and one was a verb that was not on the list at all (see Appendix B). For example, in the videoclip, the person was making a hand gesture going downwards diagonally to represent that the plane is crashing, and in the meantime, saying "the plane *crashed*" with a nonsense word (e.g., *fetti*) replaced with the action verb (e.g., *crashed*). The options were given as "*exit* (e.g., çıktı), *crashed* (e.g., düştü), *went* (e.g., gitti)" (see Figure 1). We evaluated the proportion of correct and incorrect answers based on the Qualtrics results. We divided the total correct and incorrect responses to the overall question number.

Procedure

All participants were assessed individually in a silent clinic room at Koç University Hospital. First, a neurologist examined the patients' severity of PD. If they had met the

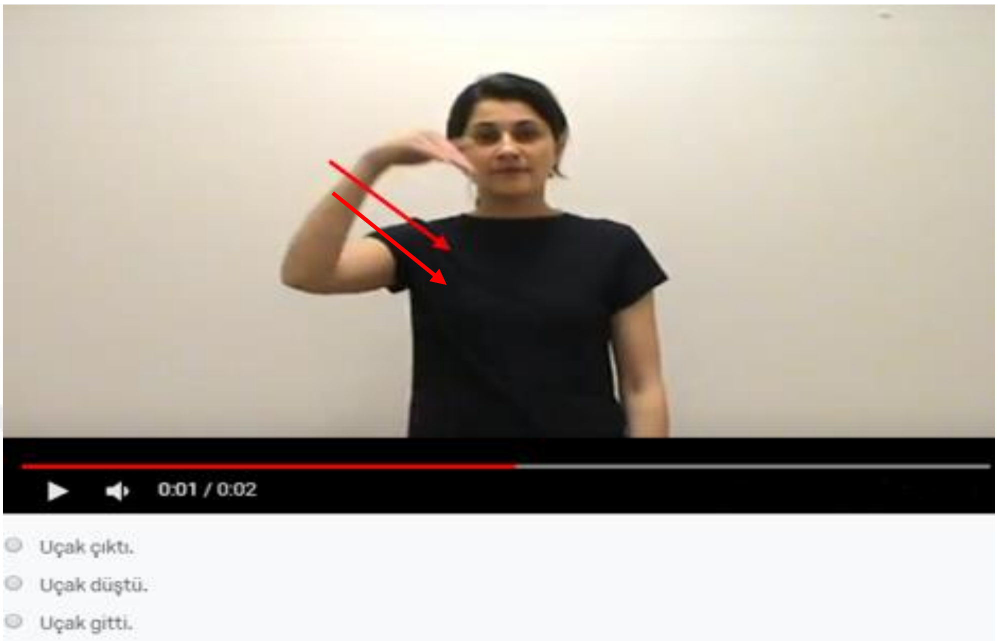

Figure 1. The videoclip demonstrating "the plane crashed." The arrows show the direction of the hand gesture.

criteria, we would have called them to the experiment room and asked them to complete a demographic information form. Then, we administered the standardized tests in the same order: Standardized Mini Mental State Exam Test, BDI, BAI, CFQ, Gülhane Aphasia Test, Boston Naming Test, Action Naming Test, Motor Praxis Test, and Letter-N-Back. Following the standardized tasks, we first administered the co-speech gesture production task. We gave participants the stories one by one and asked them to retell the story after they have read it. In the meantime, we videotaped their responses. We did not mention anything about gesture use. Each story was presented randomly to each participant. Then, we continued with the co-speech gesture comprehension task. First, we displayed the video clip, and then, asked the participant to choose the correct answer among 3 choices. The concrete and abstract action videos were presented in two blocks. Half of the participants from each group began to watch the video clips containing concrete action gestures at first, and then, carried on with abstract action video clips. The other half watched the abstract action gestures first, then, continued with the concrete action gestures. The trials were presented randomly within each block. As we recruited patients, we also conducted the experiment to neurotypical participants matching the patients' age and education level.

Coding and Data Analyses

Speech Coding. A Turkish native speaker transcribed the participants' speech verbatim for each story. We count the *total number of words* used in each story, including filled pauses (e.g., *aaaa*, *eeee*) and repetitive words (e.g., going to *to* the garden). We took the *number of action verbs* used and also distinguished action verbs based on their concreteness level. In other words, we categorized actions verbs into two categories as concrete action verbs (e.g., her son was *swimming* in the sea) and abstract action verbs (e.g., the lady *went out* of work). We used ELAN software package for speech transcription and coding (Brugman, Russel, & Nijmegen, 2004). We did the speech analysis by dividing the number of concrete and abstract action verbs to the overall action verbs used within each story. To see how much of the speech contains abstract and concrete actions verbs separately, we divided each category of action verbs to the overall word count.

Gesture Coding. We coded spontaneous gestures of each participant for each story. We divided the gestures into three categories: (1) iconic, (2) pointing, (3) beat gestures and (4) others (McNeill, 1992). We also categorized the iconic gestures as (1) dynamic or (2) static gestures. Dynamic gestures referred to actions, and for the purpose of this study, we classified dynamic gestures based on what type of action verb they were referring to such as (1) abstract action or (2) concrete action. For example, a participant paddling with both hands to illustrate *swimming* was considered as a concrete dynamic action, whereas a hand movement rising from left to the right side diagonally indicating the sun *rising* was considered as an abstract dynamic action. We considered gestures referring to object property or location as static gesture. For instance, putting two palms side by side upwardly was considered to indicate a book which is a static object. Additionally, we coded which hand the participant used for gesturing. We used ELAN software package for gesture coding (Brugman et al., 2004). We considered the frequency of gestures for each utterance and informative gestures that are parallel to the speech informativeness during coding. We conducted the analysis of informative gestures by dividing the frequency of each gesture type to the overall gesture frequency.

Reliability

To ensure the coding system, two native Turkish speakers coded both speech and spontaneous gestures. The first author coded the entire participants while a second person coded 20% of the participants independently. In total, the second person coded 8 participants (i.e. 4 patients, 4 control) for reliability testing. We did the assessment by using single-rater intraclass correlation (ICC). ICC results revealed significant correlations for the production of concreteness level of action verbs (ICC= .839, $p< .05$), the overall frequency of gesture production (ICC= .90, $p< .001$) and the amount of iconic gesture used (ICC= .966, $p< .001$).

RESULTS

Neuropsychological Tests

We first analyzed if there was a group difference between PD patients and neurotypical controls in terms of age, executive functioning (i.e., MMSE), working memory (i.e., LNB), sensorimotor (i.e., MPraxis), and linguistic abilities (i.e., GAT, BNT, ANT). We also checked if the groups differed from each other regarding BDI, BAI, and CFQ scores. All these analyses revealed that there were no significant differences between two groups (*ps*>.05) except BAI and CFQ scores (*ps*<.05) (for the descriptive statistics see Table 1).

Co-speech Gesture Production Task

One of the aims of this study was to investigate if PD affects patients' use of co-speech gestures. In this part of the analyses, we had two areas to focus on: Speech and Gesture. We transformed raw scores into percentages and conducted our analyses based on these values.

Speech Analyses. First, we conducted an independent *t*-test to see whether two groups differed on the use of total action verbs in their overall speech. The results indicated that the proportion of the total action verbs used within the total speech was significantly higher in PD patients than the control group, $t(34)= 2.36$, $p< 0.05$ (see Table 2 for the descriptive statistics). Second, we conducted a repeated measures ANOVA with group (i.e., PD and control) as the between-subject variable and the action verb type (i.e., concrete vs. abstract action verbs) used over total action verbs as the within-subject variable. The results demonstrated that there was no main effect of group in the total action verbs used, $F(1, 34)= .19$, $p= .190$, $\eta_p^2= .05$. However, there was a main effect of the action verb type produced, $F(1, 34)= 448.84$, $p< .001$, $\eta_p^2= .93$. Regardless of the group, the concrete action verbs were used more than abstract action verbs. There was no interaction between the group and the type of the action verb used, $F(1, 34)= .02$, $p= .904$, $\eta_p^2= .00$ (for the descriptive statistics see Table 2).

Gesture Analyses. First, we conducted an independent t-test to see whether two groups used different amounts of gestures (i.e., iconic, beat, pointing, other) in their overall speech. The results revealed that PD patients significantly used fewer gestures in overall compared to the control group, $t(34)= -2.28$, $p< 0.05$ (for the descriptive statistics see Table 3). Second, to examine the group differences in the amount of gesture type used, we ran a repeated measures ANOVA with the group as the between-subject variable and gesture type as the within-subject variable (i.e., iconic, beat, pointing). There was no main effect of the group on the frequency of gesture use, $F(1, 34)= 2.37$, $p= .133$, $\eta_p^2= .07$. However, there was a main effect of the gesture type, $F(1, 34)= 4.48$, $p< .05$, $\eta_p^2= .12$. Based on the pairwise comparison analysis, the use of iconic gestures and beat gestures was significantly higher than the pointing gestures (p= .004 and p= .013, respectively). However, there was no significant difference between the iconic gesture and beat gesture use (p= .663). There was no interaction between the group and the type of the gesture use, F(1, 34)= .52, p= .595, η_p^2= .02 (for the descriptive statistics see Table 3).

We next compared whether two groups used the amount iconic gesture types (for concrete and abstract concepts) differently in frequency. There was no main effect of the group on the frequency of concrete iconic gestures used over the total gesture use, F(1, 34)= .35, p= .559, η_p^2= .01. Likewise, the iconic gestures representing abstract concepts did not differ between two groups, either, F(1, 34)= 1.04, p= .315, η_p^2= .03. The use of concrete iconic gestures over total iconic gestures, however, was significantly different between two groups, F(1, 34)= 5.46, p< .05, η_p^2= .14. PD patients used iconic gestures representing concrete concepts significantly less than the control group. On the other hand, this was not the case for iconic gestures representing abstract concepts, F(1, 34)= 2.07, p= .160, η_p^2= .06 (see Table 3 for the descriptive statistics).

We furthered our analysis by checking in which terms did the groups differ using iconic gestures representing concrete concepts (i.e., static, dynamic, other). The results showed that among the concrete iconic gesture types used over the total iconic gestures, only the gestures representing dynamic (i.e., action) concepts was significantly different between two groups, F(1, 34)= 6.50, p< .05, η_p^2= .16. As mentioned above, PD patients used fewer iconic gestures representing concrete actions than the neurotypical controls. However, the use of iconic gestures representing static concepts or any other concrete concepts (i.e., numbers, prepositions, spatial information such as on, back) did not differ between two groups (for descriptive statistics see Table 3).

Speech-Gesture Analyses. To assure if there was a compensatory mechanism in which poor description of dynamic events would affect the use of gestures, we conducted correlational analyses between speech and gesture production for PD patients separately and for all participants. We found no significant correlations among PD patients' speech and gesture use ($ps > .05$), meaning that there were no associations between the production of action verb types and the total amount of gesture use as well as the type of gestures use (see Table 4). When we take the entire participants into account, we found a significant correlation between the amount of total gesture use and overall action verbs produced ($r = -.41$, $p < .05$). Additionally, there was a significant negative relation between the total gesture use and the concrete action verb production ($r = -.39$, $p < .05$) and a positive relation abstract verb production ($r = .41$, $p < .05$) (see Table 5).

Co-speech Gesture Comprehension Task

Another aim of the present study was to investigate whether PD affects the patients' ability to interpret other people's messages given by co-speech gestures. We transformed raw scores into percentages and conducted our analyses based on these values. We ran a repeated measures ANOVA with the group and video order (concrete first vs. abstract first) as the between-subject variables, and the action verb type (concrete vs. abstract) as the within-subject variable. The results revealed that there was a main effect of the group, $F(1, 32) = 18.51$, $p < 001$, $\eta_p^2 = .37$. Overall, PD patients gave fewer correct responses to the videoclips than the neurotypical controls. There was a marginally significant main effect of the video order (whether participants watched concrete or abstract conditions first), $F(1, 32) = 3.92$, $p = .056$, $\eta_p^2 = .11$. The results also reveal a marginally significant interaction between the group and the video order, $F(1, 32) = 3.82$, $p = .060$, $\eta_p^2 = .11$ (for the descriptive statistics see Table 6).

There was also a main effect of concreteness on the correct answers given by the participants, $F(1, 32)= 35.51$, $p< .001$, $\eta_p^2= .53$ and a significant interaction between the group and concreteness level, $F(1, 32)= 12.19$, $p= .001$, $\eta_p^2= .28$. The correct responses given by the controls to the concrete co-speech gesture videoclips were significantly higher than the PD group’s responses. Likewise, the correct responses given by the controls to the abstract co-speech gesture videoclips were also significantly higher than the PD group’s responses. Additionally, PD group gave more correct responses to the concrete co-speech gesture videoclips than the abstract co-speech gesture videoclips, $t(34)= -2.36$, $p< 0.05$ (for the descriptive statistics see Table 6). To see if the PD group’s performance was above chance level for each video condition, we conducted one-sample t-tests. The results revealed that PD patients performance was above chance level for both videoclip conditions, $t(17)= 32.89$, $p< 0.001$ and $t(17)= 12.83$, $p< 0.001$, for concrete actions and abstract actions, respectively.

Correlational Analyses with Neuropsychological Tests

Co-Speech Gesture Production Task. For PD patients, there was no significant correlation between the Unified Parkinson's Disease Rating Scale-III (UPDRSIII) scores, and concrete action verbs used over the total action verbs used as well as the abstract action verbs used (*ps*> .05). This was also the case for Hoehn and Yahr (H&Y) scores (*ps*> .05) (for details see Table 5). Additionally, there was no significant relation between the Motor Praxis (MPraxis) Task, and the action verbs used during the speech, regardless the type of the action verb (*ps*> .05) (for details see Table 4).

Based on the gesture analyses results, patients’ score on UPDRSIII had a marginally significant relation with the overall gesture use within the speech in a negative direction ($r= -.45$, $p= .06$). Meaning that as PD patients got higher scores on UPDRSIII, their use of gesture during the speech decreased. On the other hand, there was no meaningful relation with the MPraxis Task, and the gesture types used when taking all the participants into account (*ps*>

.05) (for details see Tables 4). When controlling for MPraxis Task, the results revealed a significant negative correlation between UPDRSIII scores and total gesture use within speech (r= -.79, p< .001) as well as concrete iconic gestures (r= -.65, p< .05) and iconic gestures representing dynamic events (r= -.54, p< .05) for PD patients (for details see Table 7).

Co-Speech Gesture Comprehension Task. For PD patients, as the severity of the Unified Parkinson's Disease Rating Scale-III (UPDRSIII) scores increased, the correct responses given to abstract action videoclips in the gesture comprehension task decreased significantly (r= -.54, p< .05). However, this significant relation was not observed with concrete action videoclips (r= -.39, p= .107) (see Table 8). Overall, as the reaction time given to Motor Praxis Task increased, the accurate responses given to videoclips containing gestures representing both concrete (r= -.48, p< .05) and abstract (r= -.43, p< .05) action verbs decreased, meaning that as the ability to process the motoric information got worse, the participants' chance to comprehend the other party's gesture representing an action, regardless the type of the action, also decreased (for details see Table 9).

Relation Between Co-Speech Gesture Comprehension and Production Task

The focus of this analysis is to see if co-speech comprehension task and co-speech production task were related to each other. That is, our aim was to investigate whether there was a bidirectional effect between these two mechanisms. The results showed that there was no significant relation between these two tasks (ps> .05), meaning that the outcomes of these two mechanisms seems not to be related to each other in this study (for details see Table 10). We also ran partial correlations by controlling the Action Naming Task and the Boston Naming Task and the results remained the same (for details see Tables 11 and 12).

DISCUSSION

The present study investigated whether having sensorimotor problems would affect the understanding and the use of co-speech gestures. In particular, we focused on PD patients who have motor problems that might in turn influence their nonverbal communicative skills (Cleary et al., 2011) beside their physical conditions (Kemmerer et al., 2013). We asked whether PD affected patients' ability to (1) produce iconic gestures when they talked and (2) comprehend iconic gestures in terms of matching a gesture with a novel word. We also examined these questions for action events that included different levels of spatio-motoric details: actions that were represented in concrete terms or in abstract terms. We hypothesized that (1) in terms of co-speech gesture production, if PD did not affect patients' conceptualization of action, patients would produce more co-speech iconic gestures to compensate their speech impairment while explaining concrete and abstract action events. However, if PD influenced their conceptualization of actions, then, patients would produce fewer iconic gestures during speech and could not deliver their messages regarding to both types of action. (2) In terms of co-speech gesture comprehension, if PD affected patients' conceptualization of actions, patients would make more errors in both concrete and abstract action events since they cannot attribute meaning to the gestures shown in the videoclips. However, if the disease did not have an effect at the conceptual level, then, there would be no difference in the accuracy rate between the patient group and the control group for both action types. Last, we asked if co-speech gesture comprehension and production dissociated from each other. (3) If this was the case, then, problems in one mechanism would not influence the other, that is, there would be no spillover effect between two tasks' performance.

Our findings on co-speech gesture production task revealed that compared to controls, overall, PD patients produced more action verbs. Both groups used abstract action verbs less than concrete action verbs during their speech. In terms of gesture use, they employed similar amount of gestures with the controls while telling the story. Yet, there were minor differences in terms of the type of gestures they employed such that PD patients used fewer iconic gestures reflecting concrete dynamic events. In the co-speech gesture comprehension task, PD patients showed lower performance on finding the corresponding action verb to the gesture they watched on the videoclip, and this was the case for both action types. In other words, patients had difficulties in finding the correct responses to the gestures demonstrating both concrete and abstract actions compared to controls. Moreover, PD patients had more trouble in answering abstract actions relatively to the concrete actions. Last, we found no association between two tasks which points out that these two profiles may be dissociated from each other.

Co-speech Gesture Production in PD Patients

In the co-speech gesture production task, considering the proportion of action verbs used over the total word count, PD patients used more action verbs than the neurotypical participants. However, among the total action verbs, PD patients used concrete and abstract action verbs similar to the neurotypical participants. In other words, PD patients used fewer words in their entire speech, therefore, the proportion of action verbs used was seemingly higher than the neurotypical participants. Yet, when we consider the proportion of concrete and abstract action verbs used over total action verbs, the distribution was similar for both patients and neurotypical participants. In one of the studies related to the speech impairments in PD patients, Herrera et al. (2012) found that patients made more errors in naming complicated actions compared to simple actions. Similarly, Bocanegra et al. (2015) indicated that PD patients with or without mild cognitive impairment showed low performance in action-verb processing at both understanding the semantic meaning of actions and naming the action. While these studies showed that PD influenced patients' performance to produce action verbs, our results contradicted with these findings. This difference may be due to the task differences. In previous studies, patients were asked to produce action verbs based on what they were shown in the pictures. To name those actions, they should first recognize and comprehend the action that they saw without any semantic cue and then, produce the corresponding action verb with one or two words. In our study, participants were not exposed to actions visually but instead they were provided with a written manuscript. Thus, the participants had a chance to connect the semantic cues from the content of the stories and express those actions with the help of gestures. As suggested by the Lexical Retrieval Hypothesis earlier, gestures ease the lexical access during speech, assist the person in expressing words related to spatial content such as action verbs, therefore, gestures can facilitate speaker's cognitive load (Krauss, Chen, & Gottesman, 2000).This brings us to the second component of our task: the use of co-speech gestures.

Previous research examining the use of gestures focused on the quantitative aspect of gesture use (i.e., overall frequency). It is also important to examine the frequency and distribution of different gesture types. When we look at the overall frequency of gestures used within speech, PD patients significantly differed from the control group. However, when we analyze the difference between gesture types, iconic gesture use did not significantly differ between two groups, meaning that PD did not affect the use of iconic gesture frequency in overall. Similarly, the frequency of iconic gesture use representing concrete (i.e., including static, dynamic, prepositions, numbers, etc.) and abstract (i.e., includes only dynamic) concepts were also similar between two groups. This was also the case for beat and pointing gestures. When we focus on the distribution of the iconic gesture types within itself, especially the distribution of iconic gestures representing concrete concepts (i.e., specifically dynamic) was significantly fewer in PD patients than neurotypical controls. However, there was no significant difference between groups regarding to the distribution of iconic gestures representing abstract concepts. Humphries et al. (2016) found that the overall gesture use and different gesture types (i.e., iconic, metaphoric, deictic) did not differ between PD patients and neurotypical participants; however, the viewpoint that they took differed. While controls were employing character-viewpoint in their gestures, PD patients were using observer-viewpoint. Cleary et al. (2011) also had similar results in which they found no significant difference in terms of the amount of gesture use, however, the informativeness of iconic gestures representing actions used by PD patients was fewer in number. Overall, these studies suggest that even though the frequency of gesture use does not significantly differ from neurotypical participants, PD still causes some changes in the way patients produced iconic gestures. They explain these alterations by the changes occurred in mental representations associated with actions. Our results did not support these two studies in terms of the overall gesture use within speech. This could be due the tremors seen in PD patients which might deduce embarrassment for them. However, our results related to gesture type use was in the same line with the aforementioned studies. Our results indicated that the total iconic gesture use (i.e., regardless what it referred to) was not affected by PD in terms of frequency. Yet, when we narrow down the focus to the distribution of iconic gesture types within itself, patients produced iconic gestures representing concrete actions fewer than neurotypical participants did. But this was not the case for other components of concrete concepts (i.e., static, other) that did not require sensorimotor representations.

In addition to the possibility that PD patients might have altered sensorimotor representations, the properties of the task might have also affected the outcome. In the Interface Model, Kita and Özyürek (2003) indicated that language processes involving both speech and gestures highly reflect the sensorimotor representations accompanied by spatial details of the speaker. Based on GSA framework, Hostetter and Alibali (2019) elaborate on their explanation by addressing that as these representations get prominent, the possibility to reach the gesture threshold also increases, thus, the individual will be more likely to gesture. If we have presented our task with visual images rather than a written manuscript, then, the probability of seeing iconic gestures representing concrete actions would also be higher in PD patients. Under normal circumstances, a written manuscript would be enough for neurotypical participants to be simulated by action verbs; however, PD patients seem to be less simulated by the action verbs that they read. These findings highlight the importance of the task's properties in which using a task including visual imagery prompts individuals to gesture more compared to tasks involving only verbal information (Hostetter & Alibali, 2019). In a study Hostetter and Skirving (2011) introduced participants descriptions twice and then, asked them to explain what they learned. One group *listened* to the description twice (i.e., auditory stimuli) whereas the other group *listened* (i.e., auditory stimuli) once and *watched* the description in a cartoon (i.e., visual stimuli). Then, they compared the amount of representational and beat gestures speakers used while explaining the descriptions. The results showed that the group that only listened to the description gestured less than the other group. This finding suggests that the participants were prone to gestures more when visual stimuli was present in the task. In future studies, presenting the stories as cartoons to the PD patients could hold light to this issue. Providing actions with salient stimuli may increase the activation in motor-related areas and patients might be able to produce more gestures, and particularly iconic gestures during speech.

Here, the question is why the distribution of iconic gestures representing abstract actions was not significantly different between two groups while concrete actions was. If abstract actions share the common features with concrete actions as Talmy (2002) suggested, then, we would also expect PD to influence the way patients use iconic gestures representing abstract actions in negative terms. Previous studies reported no significant differences between PD patients and neurotypical controls regarding metaphoric gesture use (Cleary et al., 2011; Humphries et al., 2016). Yet, it was not clear how they define metaphoric gestures. Therefore, in the literature, our study would be the first to specifically examine the expression of abstract action verbs with the help of gestures. As it was also seen in the co-speech gesture comprehension task results, PD patients may have more difficulties in processing the contents involving abstract meanings compared to concrete ones. In this task, participants had to comprehend the meaning of the abstract action verbs first, and then, they had to express what they understood. With the help of the semantic cues provided in the story, it might be easier for them to understand the meaning of the abstract action verbs compared to the comprehension task (i.e., note that this task involved novel verbs), but to express those actions they might need to use more gestures to have lexical access to those words (Krauss et al., 2000). Further investigation is required on this matter.

Co-speech Gesture Comprehension Task

In the co-speech gesture comprehension task, we found that PD had an impact on how patients interpret the messages delivered through gestures related to both types of actions. Patients made more errors than neurotypical participants in attributing meaning to the gestures reflecting concrete actions. In the same line, patients also had difficulties in recognizing iconic gestures representing abstract actions. Additionally, PD patients performed worse in the abstract action events condition than concrete action events condition. These results are the first in the literature reflecting PD patients' condition concerning co-speech gesture comprehension. The existing literature on PD patients mainly focuses on either co-speech gesture production (e.g., Cleary et al., 2011; Humphries et al, 2016) or gesture comprehension for emotional gestures or communicative gestures (Lotze et al., 2009; Jaywant et al., 2016) alone. These studies do not provide a wholistic picture regarding iconic gestures representing different action events during speech. However, our study gave the chance to evaluate PD patients' condition in a comprehensive approach via the task that we developed for co-speech gesture comprehension. Previous studies focused mainly on the integration of information stemming from speech and gestures *separately* (e.g., Kelly et al., 2015; Kelly et al., 2004; Kelly et al., 2010; Özyürek et al., 2007). Therefore, we developed a task in which participants could observe iconic gestures reflecting either concrete or abstract actions associated with the content of the discourse *concurrently*. But the important detail here is that based on the content of the speech and the gesture that they watched, they required to find the accurate action verb that should be replaced with the nonsense (i.e., novel) word. The main point of this assessment was to see if the participant could map the action embedded to the gesture with the existing mental representations that they had associated with that particular action. If they could do the mapping, then it would be possible for them to correctly find the action verbs corresponding to the novel words. Yet, the results suggested that PD patients might be struggling with the *embodiment problem*, in which they cannot map the action that they observe with the preexisting mental representation related to that action. Thus, they had trouble finding the correct corresponding action verb. Besides, they experienced this mapping problem especially with the abstract actions demonstrated in the videoclips compared to concrete actions. Our findings suggest that even though patients performed the task above chance level (i.e., they can map the mental representation and the action that they observe), their performance was still significantly worse than the neurotypical participants.

As mentioned earlier, the ECT suggests that as we interact with the outside world, we constantly constitute perceptual and motor representations that we use to comprehend and produce further actions (Wilson, 2002). On this matter, the GSA framework highlighted the central role of embodied cognitive system and proposed that perceptual and motor representations containing spatial information also has a key role on linguistic statements and gestures (Hostetter & Alibali, 2008; Hostetter & Alibali, 2019) such as iconic gestures representing actions during speech. Apart from the mental representations, the significance of motor-related areas was pointed out by previous studies for iconic gestures representing both concrete and abstract concepts (Özyürek et al., 2007; Kircher et al., 2009). In the light of these information, it is possible to speculate that a person with a problem affecting the motor-related areas may encounter with obstacles in formulating mental representations and it may inevitably affect the person's way of communicating actions as demonstrated by earlier studies with different patient groups (e.g. Ali et al., 2015; Cleary et al., 2011; Cocks et al., 2009; Fernandino et al., 2013; Göksun et al., 2015, Herrera et al., 2012; Humphries et al., 2016). Therefore, considering PD patients' condition related to motor problems, these findings support the claim that PD patients might have an embodiment problem that resulted in low accuracy rate in interpreting the iconic gestures representing both action types compared to controls. In one study, Kloeters and her colleagues (2016) found that patients had lower recognition of human movements especially with those including objects or goal-directed actions such as kicking a soccer ball or throwing an object. In linguistic terms, our videoclips expressing action events also contained objects and goal-directed actions such as stirring the soup, catching the thief. Taking into Kloeters et al. (2016)'s study into account, we may also speculate that PD does not only affect the way they perceive and comprehend human movements, but also affects the patients' ability to perceive and comprehend gestures representing those human movements.

Even though the ECT and GSA frameworks brought an explanation to our findings, it is important to keep in mind that all these results may not be entirely depending on the embodiment issue. In other words, having lower accuracy rate in the task may not necessarily mean that the patient did not understand the hand gesture indicating a movement such as *cutting* or *raising.* The cognitive load in this task was not only limited with mapping the co-speech gesture with the target action's mental representation, but also to find the convenient action verb in a novel instance. Patients performed lower in both action types compared to controls, but they were worse in abstract actions especially. In both occasions, they saw the same gesture but with different wordings and different contents. If it was entirely about the embodiment issue, then we would not see a significant difference between the action categories since they would not be able to map the action in either case. Yet, results demonstrate that patients were more successful in mapping the concrete actions with preexisting mental representations than abstract actions. Even though concrete and abstract actions share a common platform in linguistic settings (Talmy, 2000), it seems that PD patients have more difficulty in interpreting abstract contents than concrete ones. Our correlational analyses with UPDRSIII scores also support our explanation by showing us that as the severity of the disease increased, patients’ accuracy rate on the videoclips showing gestures related to abstract actions decreased. However, the negative correlation between the severity of PD and the patients’ accuracy rate on the videoclips with concrete action gestures was not significant. Overall, our findings may suggest that spatio-motoric details for abstract action events may have a common underlying system with the concrete action events (Talmy, 2000); yet, they do not entirely overlap, and PD may have more effect on spatio-motoric representations related to abstract actions than concrete actions.

Our final research question was related to the association between co-speech gesture comprehension and co-speech gesture production task. Our correlational analyses between these two tasks revealed no significant results, meaning that low performance in one task did not have a relation with the performance in the other task. These results were also the same when ran the same analyses controlled for the Action Naming Task and Boston Naming Task. There are no studies explaining the underlying mechanism of co-speech gesture comprehension extensively, however, the gesture-speech integration studies (Kelly et al., 2015; Kelly et al., 2004; Kelly et al., 2010; Özyürek et al., 2007; Willems & Hagoort, 2007) provide some information regarding to the gestures’ function in language comprehension. These studies suggested that comprehension and production of speech and gestures share the same mechanism. However, we failed to support this suggestion and conclude that comprehending and producing co-speech iconic gestures are two separate mechanisms.

Theoretical Implications

Our study adds evidence to the weaker view of the ECT, which claims that even if the mind does not directly interact with the outside world, it still makes use of the preexisting mental representations (Borghi & Cimatti, 2010; Garbarini & Adenzato, 2004; Barsalou, 2008), and through these representations we are able to comprehend and produce action-related language processes (Wilson, 2002). On this matter, the GSA framework puts emphasis on the embodied cognitive system and indicates the key role of perceptual and motor representations in processing linguistic statements and gestures. According to this view, articulating linguistic statements associated with actions activates the motor-related areas, and results in perceptual and motor simulation. If these simulations are strong enough, they result in a domino effect and produce gestures related to that action (Hostetter & Alibali, 2008, 2019). Our study investigated whether having an impairment associated with the motor system such as Parkinson's Disease affects the communication skills of the patients in terms of their comprehension and production of co-speech gestures. Taking into the ECT and GSA frameworks into account, we assumed that distortions in motor system would affect patients' perceptual and motor simulation. As a result, the sensorimotor representations required to comprehend and produce co-speech gestures representing different action types would also be affected.

We took our strength from the Interface Model, which points out that representational gestures benefit from the sensorimotor representations accompanied by spatial representations (Kita & Özyürek, 2003). To be more specific, this model suggests the root of linguistic processes is the communication planner (i.e., also known as conceptualizer) and through this root, speech and gestures are formulated with the help of action and message generator (Kita & Özyürek, 2003). A problem occurring in the conceptualizer will cause the individual to have a communication problem in overall. However, having a problem in one of these generators will not necessarily affect the communication skills due to the compensatory mechanism of the generators (e.g., Akhavan et al., 2018; Göksun, Lehet, Malykhina, & Chatterjee, 2015; Iverson & Braddock, 2011; Kita & Lausberg, 2008; Kong, Law, Wat, & Lai, 2015; Özer et al., in press; Sekine & Rose, 2013). In the scope of our study, if the patient had a conceptual problem regarding the action types such as distorted sensorimotor representations, this would result in an inability to express actions. Yet, if the problem is only about the motor generator, then, with the help of medication patients would be able to produce co-speech gestures since the conceptual knowledge is intact. Our findings on the co-speech gesture production task support the Interface Model. Patients who were on medication did not show any deficiency in producing co-speech iconic gestures representing both types of actions in terms of the frequency. However, when we shift our focus to the components of concrete and abstract concepts, we can find some minor differences between groups in terms of their distribution within total iconic gesture use. Iconic gestures demonstrating concrete actions were significantly fewer compared to controls. This might be due to the strength of the simulation that did not reach the threshold as indicated by the GSA framework (Hostetter & Alibali 2019). While written manuscripts was sufficient to simulate sensorimotor representations of neurotypical participants, it was not enough for PD patients. This was not the case for other components of concrete concepts (i.e., static, other) or abstract actions. These findings indicate that PD did not affect the patients at the conceptual level entirely but the sensorimotor representations regarding to concrete actions might be prone to be distorted as the disease progress. To find out, further studies should be conducted with PD patients in the late phases of the disease.

As indicated earlier, there are no comprehensive framework focusing on co-speech gesture comprehension. Bimodal speech integration studies suggested that comprehension of speech and gestures share the same linguistic processes with the production of speech and gestures (Kelly, Healey, Özyürek, & Holler, 2015; Kelly, Kravitz, & Hopkins, 2004; Kelly, Özyürek, & Maris, 2010; Özyürek, Willems, Kita, & Hagoort, 2007; Willems & Hagoort, 2007). However, our findings on co-speech gesture comprehension task failed to support this suggestion. While findings of co-speech gesture production task indicated minor differences between two groups, co-speech gesture comprehension task showed us that there was a major discrepancy between two groups' performance for both action types. The correlational analysis between two tasks were also not significant event when we ran the same analyses controlling for the Action Naming Task or the Boston Naming task, which suggests that these two profiles might not be sharing same linguistic processes. Yet, it is important to keep in mind that this could be due to the task's cognitive demand in which interpreting novel instances may not be as easy as it is for PD patients. Thus, further studies are needed to clarify the link between co-speech gesture comprehension and production.

Apart from the theoretical implications, the findings also provide us some information that can be used in clinical settings. As mentioned earlier, PD is a multicentric neurodegenerative disorder that does not only influence the movement capability, but also has negative effects on the non-motor aspects of the individual such as executive functioning, mood state, sleep quality, and communicative skills (see Bartels & Leenders, 2009; Cleary et al., 2009; Williams-Gray, Foltynie, Lewis, & Barker, 2006). Limited studies on this issue pointed out that PD had an affect on the manner of their gesture production even if the amount of gesture use did not differ between two groups (Cleary et al., 2009; Humphries et al., 2016). Our study also provide evidence that PD influenced the use of iconic gestures representing concrete actions among all other iconic gestures. Besides, comprehending concrete and abstract actions were more difficult for PD patients even if they were not on the late stages of the disease. Taking all together, via tasks assessing their comprehension and production ability of co-speech iconic gestures, manifestations of the disease can be detected at the earlier stages. However, to strengthen our argument, this study should also be tested with patients who are in the very beginning of the disease.

CONCLUSION

This was the first to investigate co-speech gesture comprehension and co-speech gesture production of PD patients in the same study. The purpose was to see if PD patients can interpret and produce co-speech gestures use for action verbs at two level (i.e. concrete action vs. abstract action). We assumed that both comprehension and production use the same conceptual knowledge and mental representations for understanding and producing actions and language processes related to actions. Our results on co-speech gesture comprehension task revealed that there was a significant difference between two groups for both action types. On the other hand, our results on co-speech gesture production task demonstrated that PD did not affect the use of gestures during speech, except that iconic gestures representing concrete dynamic events among all iconic gestures were significantly different. Additionally, there was no significant correlation between two co-speech gesture comprehension and production task. Our investigation opened new doors to the complex cognitive processes underlying co-speech gestures. Future studies are required to enhance our understanding of these two mechanisms and PD patients provide a chance to further our knowledge on this matter.

REFERENCES

Akhavan, N., Göksun, T., & Nozari, N. (2018). Integrity and function of gestures in aphasia. *Aphasiology*, *32*(11), 1310-1335.

Ali, M., Lyden, P., & Brady, M. (2015). Aphasia and dysarthria in acute stroke: recovery and functional outcome. *International Journal of Stroke*, *10*(3), 400-406.

Alibali, M. W. (2005). Gesture in spatial cognition: Expressing, communicating, and thinking about spatial information. *Spatial Cognition and Computation*, *5*(4), 307-331.

Andric, M., Solodkin, A., Buccino, G., Goldin-Meadow, S., Rizzolatti, G., & Small, S.L. (2013). Brain function overlaps when people observe emblems, speech, and grasping. *Neuropsychologia*, *51*(8), 1619–1629.

Bates, E., Andonova, E., D'Amico, S., Jacobsen, T., Kohnert, K., Lu, C., ... & Iyer, G. (2000). Introducing the CRL international picture-naming project (CRL-IPNP). *Center for Research in Language Newsletter*, *12*(1), 1-14.

Barsalou, L. W. (2008). Grounded cognition. *Annuel Reviews of Psychology*, *59*, 617-645.

Bartels, A. L., & Leenders, K. L. (2009). Parkinson's disease: The syndrome, the pathogenesis and pathophysiology. *Cortex*, *45*(8), 915-921.

Beck, A. T., Steer, R. A., & Carbin, M. G. (1988). Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. *Clinical Psychology Review*, *8*(1), 77-100.

Beattie, G., & Coughlan, J. (1999). An experimental investigation of the role of iconic gestures in lexical access using the tip-of-the-tongue phenomenon. *British Journal of Psychology*, *90*(1), 35-56.

Bocanegra, Y., García, A. M., Pineda, D., Buriticá, O., Villegas, A., Lopera, F., ... & Ibáñez, A. (2015). Syntax, action verbs, action semantics, and object semantics in Parkinson's disease: Dissociability, progression, and executive influences. *Cortex, 69*, 237-254.

Borghi, A. M., & Cimatti, F. (2010). Embodied cognition and beyond: Acting and sensing the body. *Neuropsychologia*, *48*(3), 763-773.

Borreggine, K. L., & Kaschak, M. P. (2006). The action–sentence compatibility effect: It’s all in the timing. *Cognitive Science, 30*(6), 1097-1112.

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science*, *13*(2), 185-189.

Boulenger, V., Mechtouff, L., Thobois, S., Brousolle, E., Jeannerod, M., & Nazir, T. A. (2008). Word processing in Parkinson’s disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia, 46,* 743–756.

Broadbent, D. E., Cooper, P. F., FitzGerald, P., & Parkes, K. R. (1982). The cognitive failures questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, *21*(1), 1-16.

Brugman, H., Russel, A., & Nijmegen, X. (2004). Annotating Multi-media/Multi-modal Resources with ELAN. In LREC.

Buccino, G., Binkofski, F., Fink, G. R., Fadiga, L., Fogassi, L., Gallese, V., Seitz, R. J., Zilles, K., Rizzolatti, G., & Freund, H. J. (2001). Action observation activates premotor and parietal areas in a somatotopic manner: an fMRI study. *European Journal of Neuroscience, 13*(2), 400-404.

Cartmill, E. A., Beilock, S., & Goldin-Meadow, S. (2012). A word in the hand: action, gesture and mental representation in humans and non-human primates. *Philosophical Transaction of the Royal Society B: Biological Sciences*, *367*(1585), 129-143.

Casasanto, D. & Lozano, S. (2007). Meaning and Motor Action. Proceedings of 29th Annual Conference of the Cognitive Science Society (pp. 149-154). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cleary, R. A., Poliakoff, E., Galpin, A., Dick, J. P., & Holler, J. (2011). An investigation of co-speech gesture production during action description in Parkinson's disease. *Parkinsonism & Related Disorders*, *17*(10), 753-756.

Cocks, N., Sautin, L., Kita, S., Morgan, G., & Zlotowitz, S. (2009). Gesture and speech integration: An exploratory study of a man with aphasia. *International Journal of Language & Communication Disorders*, *44*(5), 795-804.

Cornejo, C., Simonetti, F., Ibáñez, A., Aldunate, N., Ceric, F., López, V., & Núñez, R. E. (2009). Gesture and metaphor comprehension: electrophysiological evidence of cross modal coordination by audiovisual stimulation. *Brain and Cognition*, *70*(1), 42-52.

Demir-Lira, Ö. E., Asaridou, S. S., Raja Beharelle, A., Holt, A. E., Goldin-Meadow, S., & Small, S. L. (2018). Functional neuroanatomy of gesture–speech integration in children varies with individual differences in gesture processing. *Developmental Science*, *21*(5), 1-15.

Desai, R. H., Binder, J. R., Conant, L. L., Mano, Q. R., & Seidenberg, M. S. (2011). The neural career of sensory-motor metaphors. *Journal of Cognitive Neuroscience*, *23*(9), 2376-2386.

Fernandino, L., Conant, L. L., Binder, J. R., Blindauer, K., Hiner, B., Spangler, K., et al. (2013). Parkinson's disease disrupts both automatic and controlled processing of action verbs. *Brain and Language*, *127*(1), 65-74.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state”: a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, *12*(3), 189-198.

Garbarini, F., & Adenzato, M. (2004). At the root of embodied cognition: Cognitive science meets neurophysiology. *Brain and Cognition*, *56*(1), 100-106.

Gibbs, R. W., Bogdanovich, J. M., Sykes, J. R., & Barr, D. J. (1997). Metaphor in idiom comprehension. *Journal of Memory and Language*, *37*(2), 141-154.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin & Review*, *9*(3), 558-565.

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008). Processing abstract language modulates motor system activity. *Quarterly Journal of Experimental Psychology*, *61*(6), 905-919.

Göksun, T., Lehet, M., Malykhina, K., & Chatterjee, A. (2015). Spontaneous gesture and spatial language: Evidence from focal brain injury. *Brain and Language, 150*, 1-13.

Grèzes, J., Armony, J. L., Rowe, J., & Passingham, R. E. (2003). Activations related to “mirror” and “canonical” neurones in the human brain: an fMRI study. *Neuroimage*, *18*(4), 928-937.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*(2), 301-307.

Herrera, E., Rodrıguez-Ferreiro, J., & Cuetos, F. (2012). The effect of motion content in action naming by Parkinson’s disease patients. *Cortex, 48*, 900–904.

Holler, J., & Beattie, G. (2003). Pragmatic aspects of representational gestures: Do speakers use them to clarify verbal ambiguity for the listener? *Gesture*, *3*(2), 127-154.

Hostetter, A. B. (2011). When do gestures communicate? A meta-analysis. *Psychological Bulletin*, *137*(2), 297.

Hostetter, A. B., & Alibali, M. W. (2008). Visible embodiment: Gestures as simulated action. *Psychonomic Bulleting & Review*,*15*(3), 495-514.

Hostetter, A. B., & Alibali, M. W. (2019). Gesture as simulated action: Revisiting the framework. *Psychonomic Bulletin & Review*, *26*(3), 721-752.

Hostetter, A. B., & Skirving, C. J. (2011). The effect of visual vs. verbal stimuli on gesture production. *Journal of Nonverbal Behavior*, *35*(3), 205-223.

Hostetter, A. B., Alibali, M. W., & Kita, S. (2007). Does sitting on your hands make you bite your tongue? The effects of gesture prohibition on speech during motor descriptions. In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 29, No. 29).

Humphries, S., Holler, J., Crawford, T. J., Herrera, E., & Poliakoff, E. (2016). A third-person perspective on co-speech action gestures in Parkinson's disease. *Cortex, 78*, 44-54.

Iverson, J. M., & Braddock, B. A. (2011). Gesture and motor skill in relation to language in children with language impairment. *Journal of Speech, Language, and Hearing Research*, *54*(1), 72-86.

Jaywant, A., Shiffrar, M., Roy, S., & Cronin-Golomb, A. (2016). Impaired perception of biological motion in Parkinson’s disease. *Neuropsychology*, *30*(6), 720.

Jaywant, A., Wasserman, V., Kemppainen, M., Neargarder, S., & Cronin-Golomb, A. (2016). Perception of communicative and non-communicative motion-defined gestures in Parkinson's disease. *Journal of the International Neuropsychological Society*, *22*(5), 540-550.

Jirak, D., Menz, M. M., Buccino, G., Borghi, A. M., & Binkofski, F. (2010). Grasping language–a short story on embodiment. *Consciousness and Cognition*, *19*(3), 711-720.

Kelly, S., Healey, M., Özyürek, A., & Holler, J. (2015). The processing of speech, gesture, and action during language comprehension. *Psychonomic Bulletin & Review*, *22*(2), 517-523.

Kelly, S. D., Kravitz, C., & Hopkins, M. (2004). Neural correlates of bimodal speech and gesture comprehension. *Brain and Language*, *89*(1), 253-260.

Kelly, S. D., Özyürek, A., & Maris, E. (2010). Two sides of the same coin: Speech and gesture mutually interact to enhance comprehension. *Psychological Science*, *21*(2), 260-267.

Kemmerer, D., Miller, L., MacPherson, M. K., Huber, J., & Tranel, D. (2013). An investigation of semantic similarity judgments about action and non-action verbs in Parkinson's disease: Implications for the Embodied Cognition Framework. *Frontiers in Human Neuroscience*, *7*, 146.

Kircher, T., Straube, B., Leube, D., Weis, S., Sachs, O., Willmes, K., Konrad, K, & Green, A. (2009). Neural interaction of speech and gesture: Differential activations of metaphoric coverbal gestures. *Neuropsychologia*, *47*(1), 169-179.

Kita, S. (2000). How representational gestures help speaking. *Language and Gesture*, (pp. 162–185). Cambridge, UK: Cambridge University Press.

Kita, S., 2014. Production of speech-accompanying gesture. In: Goldrick, M., Ferreira, V., Miozzo, M. (Eds.), Oxford Handbook of Language Production. Oxford University Press, Oxford, pp. 451-459.

Kita, S., & Lausberg, H. (2008). Generation of co-speech gestures based on spatial imagery from the right-hemisphere: Evidence from split-brain patients. *Cortex*, *44*(2), 131-139.

Kita, S., & Özyürek, A. (2003). What does cross-linguistic variation in semantic coordination of speech and gesture reveal? Evidence for an interface representation of spatial thinking and speaking. *Journal of Memory and Language, 48*, 16–32.

Kita, S., Alibali, M. W., & Chu, M. (2017). How do gestures influence thinking and speaking? The gesture-for-conceptualization hypothesis. *Psychological Review, 124*(3), 245-266.

Kloeters, S., Hartmann, C. J., Pundmann, V. D., Schnitzler, A., Südmeyer, M., & Lange, J. (2017). Impaired perception of human movements in Parkinson’s disease. *Behavioural Brain Research, 317*, 88-94.

Kong, A. P. H., Law, S. P., Wat, W. K. C., & Lai, C. (2015). Co-verbal gestures among speakers with aphasia: Influence of aphasia severity, linguistic and semantic skills, and hemiplegia on gesture employment in oral discourse. *Journal of Communication Disorders*, *56*, 88-102.

Krauss, R. M. (1998). Why do we gesture when we speak? *Current Directions in Psychological Science*, *7*(2), 54-54.

Krauss, R. M., Chen, Y., & Gottesman, R. F. (2000) Lexical Gestures and Lexical Access: A Process Model. In D. McNeill (Ed.), *Language and Gesture* (pp. 261-283). Cambridge, UK: Cambridge University Press.

Krauss, R. M., Morrel-Samuels, P., & Colasante, C. (1991). Do conversational hand gestures communicate? *Journal of Personality and Social Psychology*, *61*(5), 743.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. New York: Basic Books.

Lang, A. E., & Lozano, A. M. (1998). Parkinson's disease. *New England Journal of Medicine*, *339*(16), 1130-1143.

Lotze, M., Reimold, M., Heymans, U., Laihinen, A., Patt, M., & Halsband, U. (2009). Reduced ventrolateral fMRI response during observation of emotional gestures related to the degree of dopaminergic impairment in Parkinson disease. *Journal of Cognitive Neuroscience*, *21*(7), 1321-1331.

Lucero, C., Zaharchuk, H., & Casasanto, D. (2014). Beat gestures facilitate speech production. *Proceedings of the Annual Meeting of the Cognitive Science Society 36*(36), 897-903.

Mack, W. J., Freed, D. M., Williams, B. W., & Henderson, V. W. (1992). Boston Naming Test: Shortened versions for use in Alzheimer's disease. *Journal of gerontology*, *47*(3), 154-158.

Matlock, T. (2004). Fictive motion as cognitive simulation. *Memory & Cognition*, *32*(8), 1389-1400.

Matlock, T. (2006). Depicting fictive motion in drawings. *Cognitive Linguistics Investigations: Across Languages, Fields and Philosophical Boundaries*, *15*, 67.

Matlock, T., & Richardson, D. C. (2004). Do eye movements go with fictive motion? In *Proceedings of the Annual Meeting of the Cognitive Science Society* (Vol. 26, No. 26).

Maviş, İ., Colay, K., Topbaş, S., & Tanrıdağ, O. (2007). Standardization, validity and reliability study of Gülhane Aphasia Test-2 (GAT-2). *Turkish Journal of Neurology, 13*(2), 89-98.

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. University of Chicago Press.

Moore, T. M., Reise, S. P., Gur, R. E., Hakonarson, H., & Gur, R. C. (2015). Psychometric properties of the Penn Computerized Neurocognitive Battery. *Neuropsychology*, *29*(2), 235.

Neves, M. D. C., Albuquerque, M. R., Neves, F. S., Lage, G. M., Malloy-Diniz, L., Nicolato, R., & Corrêa, H. (2014). Sensorimotor performance in euthymic bipolar disorder: the MPraxis (PennCNP) analysis. *Revista Brasileira de Psiquiatria*, *36*(3), 248-250.

Osman, A., Kopper, B. A., Barrios, F. X., Osman, J. R., & Wade, T. (1997). The Beck Anxiety Inventory: Reexamination of factor structure and psychometric properties. *Journal of Clinical Psychology*, *53*(1), 7-14.

Özer, D., & Göksun, T. (under review). Visual-spatial and verbal abilities differentially affect sensitivity to gestural vs. spoken expressions. *Language, Cognition and Neuroscience.*

Özer, D., Göksun, T., & Chatterjee, A. (in press). Differential roles of gestures on spatial language in neurotypical elderly adults and individuals with focal brain injury. *Cognitive Neuropsychology*.

Özer, D., Tansan, M., Özer, E. E., Malykhina, K., Chatterjee, A., & Göksun, T. (2017). The effects of gesture restriction on spatial language in young and elderly adults. In G. Gunzelmann, A. Howes, T. Tenbrink, & E. Davelaar (Eds.), Proceedings of the 38th

Annual Conference of the Cognitive Science Society (pp. 1471–1476). Austin, TX: Cognitive Science Society.

Özyürek, A., Willems, R. M., Kita, S., & Hagoort, P. (2007). On-line integration of semantic information from speech and gesture: Insights from event-related brain potentials. *Journal of Cognitive Neuroscience*, *19*(4), 605-616.

Paillard, J. (1991). Motor and representational framing of space. *Brain and Space*, 163-182.

Pazzaglia, M., Smania, N., Corato, E., & Aglioti, S. M. (2008). Neural underpinnings of gesture discrimination in patients with limb apraxia. *Journal of Neuroscience*, *28*(12), 3030-3041.

Philipona, D., O'Regan, J. K., & Nadal, J. P. (2003). Is there something out there? Inferring space from sensorimotor dependencies. *Neural Computation*, *15*(9), 2029-2049.

Poliakoff, E. (2013). Representation of action in Parkinson's disease: Imagining, observing, and naming actions. *Journal of Neuropsychology, 7*(2), 241-254.

Pulvermüller, F. (2005). Brain mechanisms linking language and action. *Nature Reviews Neuroscience*, *6*(7), 576.

Pulvermüller, F., Hauk, O., Nikulin, V. V., & Ilmoniemi, R. J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience*, *21*(3), 793-797.

Richardson, D. C., Spivey, M. J., Edelman, S., & Naples, A. J. (2001). " Language is spatial": Experimental evidence for image schemas of concrete and abstract verbs. *Proceedings of the Cognitive Science Society*, *23*(23), 845-860.

Richardson, D. C., Spivey, M. J., Barsalou, L. W., & McRae, K. (2003). Spatial representations activated during real-time comprehension of verbs. *Cognitive Science*, *27*(5), 767-780.

Rodríguez-Ferreiro, J., Menéndez, M., Ribacoba, R., & Cuetos, F. (2009). Action naming is impaired in Parkinson disease patients. *Neuropsychologia*, *47*(14), 3271-3274.

Rothi, L. J., Heilman, K. M., & Watson, R. T. (1985). Pantomime comprehension and ideomotor apraxia. *Journal of Neurology, Neurosurgery & Psychiatry*, *48*(3), 207-210.

Santana, E., & De Vega, M. (2011). Metaphors are embodied, and so are their literal counterparts. *Frontiers in Psychology*, *2*, 90.

Sekine, K., Rose, M. L., Foster, A. M., Attard, M. C., & Lanyon, L. E. (2013). Gesture production patterns in aphasic discourse: In-depth description and preliminary predictions. *Aphasiology*, *27*(9), 1031-1049.

Shapiro, L. (Ed.). (2014). The Routledge handbook of embodied cognition. Routledge.

Talmy, L. (2000). *Toward a cognitive semantics*. Cambridge, Mass.: MIT press.

Willems, R. M., & Hagoort, P. (2007). Neural evidence for the interplay between language, gesture, and action: A review. *Brain and Language*, *101*(3), 278-289.

Williams-Gray, C. H., Foltynie, T., Lewis, S. J., & Barker, R. A. (2006). Cognitive deficits and psychosis in Parkinson's disease. *CNS Drugs*, *20*(6), 477-505.

Williams-Gray, C.H., Foltynie, T., Brayne, C. E. G., Robbins, T.W., & Barker, R.A. (2007). Evolution of cognitive dysfunction in an incident Parkinson's disease cohort. *Brain, 130*(7), 1787-1798.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9*(4), 625-636.

Yang, J., Andric, M., & Mathew, M. M. (2015). The neural basis of hand gesture comprehension: a meta-analysis of functional magnetic resonance imaging studies. *Neuroscience & Biobehavioral Reviews, 57*, 88-104.

Yavuzer, G., Güzelküçük, S., Küçükdeveci, A., Gök, H., & Ergin, S. (2001). Aphasia rehabilitation in patients with stroke. *International Journal of Rehabilitation Research*, *24*(3), 241-244.

Xu, J., Gannon, P. J., Emmorey, K., Smith, J. F., & Braun, A. R. (2009). Symbolic gestures and spoken language are processed by a common neural system. *Proceedings of the National Academy of Sciences, 106*(49), 20664-20669.

TABLES

Table 1. Descriptive statistics for age and neuropsychological tests.

		N	Mean	SD	*p*- value	Min	Max
	PD	18	56.5	8.16		44	76
Age	Control	18	56.61	8.88	.969	45	73
	Total	36	56.56	8.4		44	76
	PD	17	28.06	1.39		25	30
MMSE	Control	13	28.15	1.41	.855	26	30
	Total	30	28.1	1.37		25	30
	PD	17	1130.47	363.64		712	1824
MPraxis	Control	17	953.06	188.88	.084	640	1365
	Total	34	1041.77	299.2		640	1824
	PD	14	595.07	198.72		410	1051
LNB	Control	16	716.25	344.37	.257	383	1699
	Total	30	659.7	287.79		383	1699
	PD	18	81.89	0.32		81	82
GAT	Control	18	82	0	.154	82	82
	Total	36	81.94	0.23		81	82
	PD	18	30.33	0.97		28	31
BNT	Control	18	30.5	0.92	.601	28	31
	Total	36	30.42	0.94		28	31
	PD	11	31.09	1.58		27	32
ANT	Control	15	31.87	0.35	.976	31	32
	Total	26	31.54	1.1		27	32
	PD	16	11.94	10.7		0	41
BDI	Control	15	7.6	6.37	.184	0	19
	Total	31	9.84	9		0	41
	PD	16	11.88	9.58		0	32
BAI	Control	15	3.87	2.93	.004	0	9
	Total	31	8	8.15		0	32
	PD	16	23.88	13.79		6	60
CFQ	Control	15	10.8	9.28	.005	0	28
	Total	31	17.55	13.4		0	60

Table 2. Descriptive statistics for total action verbs and its types used within speech by each group.

	Group	N	Mean	SD	*p*- value	Min	Max
Total Action/	PD	18	0.21	0.04		0.16	0.28
Total Word	Control	18	0.18	0.03	0.024	0.15	0.26
	Total	36	0.2	0.04		0.15	0.28
Concrete Action/	PD	18	0.81	0.1		0.62	1
Total Action	Control	18	0.82	0.08	0.971	0.64	0.93
	Total	36	0.81	.0.9		0.62	1
Abstract Action/	PD	18	0.18	0.1		0	0.38
Total Action	Control	18	0.19	0.08	0.757	0.07	0.36
	Total	36	0.19	0.09		0	0.38

Table 3. Descriptive statistics for overall gesture use and the types gestures used by each group.

	Group	N	Mean	SD	*p*- value	Min	Max
Total Gesture/	PD	18	0.15	0.17		0	0.57
Total Word	Control	18	0.32	0.28	0.029	0	1
	Total	36	0.23	0.24		0	1
Total Iconic/	PD	18	0.28	0.28		0	0.69
Total Gesture	Control	18	0.4	0.28	0.497	0	1
	Total	36	0.34	0.28		0	1
Total Pointing/	PD	18	0.13	0.13		0	0.34
Total Gesture	Control	18	0.2	0.2	0.177	0	0.69
	Total	36	0.17	0.17		0	0.69
Total Beat/	PD	18	0.31	0.33		0	1
Total Gesture	Control	18	0.31	0.2	0.956	0	0.6
	Total	36	0.31	0.27		0	1
Concrete Iconic/	PD	18	0.25	0.26		0	0.67
Total Gesture	Control	18	0.3	0.25	0.559	0	1
	Total	36	0.27	0.25		0	1
Abstract Iconic/	PD	18	0.25	0.26		0	0.22
Total Gesture	Control	18	0.3	0.25	0.315	0	1
	Total	36	0.27	0.25		0	1
Concrete Iconic/	PD	18	0.47	0.46		0	1
Total Iconic	Control	18	0.78	0.31	0.025	0	1
	Total	36	0.63	0.41		0	1
Abstract Iconic/	PD	18	0.08	0.15		0	0.5
Total Iconic	Control	18	0.18	0.25	0.160	0	1
	Total	36	0.13	0.21		0	1
Static/ Total Gesture	PD	18	0.02	0.03		0	0.11
	Control	18	0.02	0.04	0.607	0	0.11
	Total	36	0.02	0.03		0	0.11
Dynamic/ Total Gesture	PD	18	0.19	0.21		0	0.67
	Control	18	0.26	0.24	0.324	0	1
	Total	36	0.22	0.23		0	1
Other/ Total Gesture	PD	18	0.06	0.16		0	0.66
	Control	18	0.03	0.03	0.430	0	1
	Total	36	0.04	0.11		0	1
Static/ Total Iconic	PD	18	0.03	0.07		0	0.22
	Control	18	0.07	0.11	0.185	0	0.36
	Total	36	0.05	0.09		0	0.36
Dynamic/ Total Iconic	PD	18	0.35	0.37		0	1
	Control	18	0.63	0.28	0.015	0	1
	Total	36	0.49	0.36		0	1
Other/ Total Iconic	PD	18	0.1	0.23		0	0.96
	Control	18	0.08	0.10	0.771	0	0.27
	Total	36	0.09	0.18		0	0.96

Table 4: Correlations among neuropsychological tests and co-speech gesture production task for PD patients, *p < .05, **p < .001.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. H & Y	1															
2. UPDRSIII	.573*	1														
3. MPraxis	.512*	.646**	1													
4. ANT	.191	-.220	-.357	1												
5. BNT	-.494*	-.551*	-.733**	.786**	1											
6. Total Action / Total Word	.116	.183	-.193	.303	.048	1										
7. Concrete Action / Total Action	-.316	-.038	-.104	.406	.444	-.064	1									
8. Abstract Action / Total Action	.315	.061	.121	-.432	-.435	.024	-.908**	1								
9. Total Gesture / Total Word	-.098	-.449	.216	-.145	-.293	-.312	-.319	.341	1							
10. Total Iconic / Total Gesture	-.318	-.305	.027	-.010	.145	-.286	-.254	.347	.398	1						
11. Concrete Iconic / Total Gesture	-.247	-.426	.106	-.025	.024	-.019	-.229	.290	.599**	.684**	1					
12. Abstract Iconic / Total Gesture	.301	.310	.375	.071	-.269	-.133	.131	.079	.165	.148	.166	1				
13. Static / Total Gesture	-.065	-.476*	-.180	.253	.193	-.314	.089	-.099	.469*	.215	.386	.041	1			
14. Dynamic / Total Gesture	-.162	-.342	.104	.189	.078	-.216	-.210	.259	.556*	.550*	.801**	.250	.362	1		
15. Total Pointing / Total Gesture	.169	-.123	.110	.285	-.250	.193	-.333	.480*	.610**	.366	.535*	.404	.127	.506*	1	
16. Total Beat / Total Gesture	-.012	-.209	-.355	-.252	-.054	.010	-.149	.027	.020	-.329	-.188	-.022	.021	-.151	-.009	1

Table 5: Correlations among neuropsychological tests and co-speech gesture production task for all participants, $*p < .05$, $**p < .001$.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. MPraxis	1													
2. ANT	-.448*	1												
3. BNT	-.603**	.400*	1											
4. Total Action / Total Word	.101	.032	-.289	1										
5. Concrete Action/ Total Action	.062	.218	.133	.092	1									
6. Abstract Action / Total Action	-.044	-.244	-.183	-.098	-.921**	1								
7. Total Gesture / Total Word	-.172	.117	.006	-.405*	-.388*	.407*	1							
8. Total Iconic / Total Gesture	.072	.001	.183	-.165	-.144	.209	.015	1						
9. Concrete Iconic / Total Gesture	.134	-.060	.072	-.067	-.050	.096	.179	.661**	1					
10. Abstract Iconic / Total Gesture	.034	.076	.052	.000	-.114	.158	-.090	.400*	-.133	1				
11. Static / Total Gesture	-.283	.208	.253	-.415*	-.125	.092	.504**	.033	.158	-.071	1			
12. Dynamic / Total Gesture	.116	.104	.103	-.162	-.014	.053	.099	.600**	.890**	-.099	.061	1		
13. Total Pointing / Total Gesture	-.054	.174	-.331*	.038	-.105	.149	.386*	-.068	.083	-.091	.163	.043	1	
14. Total Beat / Total Gesture	-.281	-.151	-.050	.012	-.035	-.009	.149	-.345*	-.171	-.192	.107	-.173	-.016	1

Table 6. Descriptive statistics for co-speech gesture comprehension task.

	Group	Video Order	Mean	SD	N
Correct Concrete Response	PD	Concrete	95.00	6.67	10
		Abstract	90.00	8.45	8
		Total	92.78	7.71	18
	Control	Concrete	97.50	5.40	10
		Abstract	98.13	3.72	8
		Total	97.78	4.61	18
	Total	Concrete	96.25	6.04	20
		Abstract	94.06	7.58	16
		Total	95.28	6.76	36
Correct Abstract Response	PD	Concrete	85.50	6.85	10
		Abstract	71.25	19.41	8
		Total	79.17	15.27	18
	Control	Concrete	94.50	4.38	10
		Abstract	93.75	5.18	8
		Total	94.17	4.62	18
	Total	Concrete	90.00	7.26	20
		Abstract	82.50	17.98	16
		Total	86.67	13.47	36

Table 7: Correlations among neuropsychological tests and co-speech gesture production task controlling for Motor Praxis (Mpraxis) Task, for PD patients *p < .05, **p < .001.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. H&Y	1														
2. UPDRSIII	0.37	1													
3. ANT	0.47	0.01	1												
4. BNT	-0.20	-0.15	0.83*	1											
5. Total Action / Total Word	0.26	0.41	0.26	-0.14	1										
6. Concrete Action / Total Action	-0.31	0.04	0.40	0.54	-0.09	1									
7. Abstract Action / Total Action	0.30	-0.02	-0.42	-0.51*	0.05	-0.91**	1								
8. Total Gesture / Total Word	-0.25	-0.79**	-0.07	-0.20	-0.28	-0.31	0.33	1							
9. Total Iconic / Total Gesture	-0.39	-0.42	0.00	0.24	-0.29	-0.25	0.35	0.40	1						
10. Concrete Iconic / Total Gesture	-0.35	-0.65*	0.01	0.15	0.00	-0.22	0.28	0.59*	0.69*	1					
11. Abstract Iconic / Total Gesture	0.14	0.10	0.24	0.01	-0.07	0.18	0.04	0.09	0.15	0.14	1				
12. Static / Total Gesture	0.03	-0.48	0.21	0.09	-0.36	0.07	-0.08	0.53*	0.22	0.41	0.12	1			
13.Dynamic / Total Gesture	-0.25	-0.54*	0.24	0.23	-0.20	-0.20	0.25	0.55*	0.55*	0.80**	0.23	0.39	1		
14. Total Pointing / Total Gesture	0.13	-0.26	0.35	-0.25	0.22	-0.33	0.47*	0.60*	0.37	0.53*	0.39	0.15	0.50*	1	
15. Total Beat / Total Gesture	0.21	0.03	-0.43	-0.50*	-0.06	-0.20	0.08	0.11	-0.34	-0.16	0.13	-0.05	-0.12	0.03	1

Table 8: Correlations among neuropsychological tests and co-speech gesture comprehension task for PD patients, **p* < .05.

	1	2	3	4	5	6	7
1. H & Y	1						
2. UPDRSIII	.573*	1					
3. ANT	.191	-.220	1				
4. BNT	-.494*	-.551*	.786**	1			
5. MPraxis	.512*	.646**	-.357	-.733**	1		
6. Correct Concrete Response	-.289	-.393	.735**	.380	-.467	1	
7. Correct Abstract Response	-.392	-.543*	.463	.417	-.420	.558*	1

Table 9: Correlations among neuropsychological tests and co-speech gesture comprehension task for all participants, *p < .05, **p < .001.

	1	2	3	4	5
1. ANT	1				
2. BNT	.400*	1			
3. MPraxis	-.448*	-.603**	1		
4. Correct Concrete Response	.631**	.365*	-.477**	1	
5. Correct Abstract Response	.487*	.283	-.428*	.646**	1

Table 10: Correlations among co-speech gesture comprehension and co-speech gesture production task for all participants, **p* < .05, ***p* < .001.

	1	2	3	4	5	6	7	8	9
1. ANT	1								
2. BNT	.400*	1							
3. Correct Concrete Response	.631**	.365*	1						
4. Correct Abstract Response	.487*	.283	.646**	1					
5. Concrete Action / Total Action	.218	.133	.202	.193	1				
6. Abstract Action / Total Action	-.244	-.183	-.158	-.171	-.921**	1			
7. Concrete Iconic / Total Gesture	-.060	.072	.043	.095	-.050	.096	1		
8. Abstract Iconic / Total Gesture	.076	.052	.145	.064	-.114	.158	-.133	1	
9. Dynamic / Total Gesture	.104	.103	.030	.192	-.014	.053	.890**	-.099	1

Table 11: Correlations among co-speech gesture comprehension and co-speech gesture production task controlling for Action Naming Task (ANT) for all participants, *$p < .05$, **$p < .001$.

Control Variables		1	2	3	4	5	6	7	8
-none-	1. Correct Concrete Response	1							
	2. Correct Abstract Response	.488*	1						
	3. Concrete Action / Total Action	.086	-.029	1					
	4. Abstract Action / Total Action	-.027	-.008	-.957**	1				
	5. Concrete Iconic/ Total Gesture	-.064	-.175	-.157	.122	1			
	6. Abstract Iconic/ Total Gesture	.208	.105	-.159	.190	-.213	1		
	7. Dynamic / Total Gesture	-.046	.074	-.097	.059	.874**	-.169	1	
	8. ANT	.631*	.487*	.218	-.244	-.060	.076	.104	1
ANT	1. Correct Concrete Response	1							
	2. Correct Abstract Response	.267	1						
	3. Concrete Action / Total Action	-.068	-.158	1					
	4. Abstract Action / Total Action	.169	.131	-.955**	1				
	5. Concrete Iconic/ Total Gesture	-.034	-.167	-.148	.111	1			
	6. Abstract Iconic / Total Gesture	.207	.079	-.181	.215	-.210	1		
	7. Dynamic / Total Gesture	-.145	.027	-.123	.087	.887**	-.178	1	

Table 12: Correlations among co-speech gesture comprehension and co-speech gesture production task controlling for Boston Naming Task (BNT) for all participants, $*p < .05$, $**p < .001$.

Control Variables		1	2	3	4	5	6	7	8
-none-	1. Correct Concrete Response	1							
	2. Correct Abstract Response	.646**	1						
	3. Concrete Action / Total Action	.202	.193	1					
	4. Abstract Action / Total Action	-.158	-.171	-.921**	1				
	5. Concrete Iconic/ Total Gesture	.043	.095	-.050	.096	1			
	6. Abstract Iconic/ Total Gesture	.145	.064	-.114	.158	-.133	1		
	7. Dynamic / Total Gesture	.030	.192	-.014	.053	.890**	-.099	1	
	8. BNT	.365	.283	.133	-.183	.072	.052	.103	1
BNT	1. Correct Concrete Response	1							
	2. Correct Abstract Response	.608**	1						
	3. Concrete Action / Total Action	.167	.163	1					
	4. Abstract Action / Total Action	-.100	-.127	-.920**	1				
	5. Concrete Iconic/ Total Gesture	.018	.079	-.060	.111	1			
	6. Abstract Iconic/ Total Gesture	.136	.051	-.123	.170	-.138	1		
	7. Dynamic / Total Gesture	-.008	.171	-.028	.074	.890**	-.105	1	

APPENDIX A

The aim of this test is to see whether participants can name the actions presented in the pictures. Based on the answers, we marked the corresponding boxes (i.e., knew the answer/ received help and knew the answer/ could not know the answer) and added up only the known ones.

Checklist for Action Naming Test

Fiil (Verb)	Bildi (knew the answer)	Yardım aldı ve bildi (received help and knew the answer)	Bilemedi (could not know the answer)
Top sektirmek / oynamak (bouncing ball)			
Diş fırçalamak (brushing teeth)			
Kovalamak / yakalamak (catching)			
Alkışlamak (applauding)			
Taramak (combing)			
Emeklemek (crawling)			
Sigara içmek (smoking)			
Ağlamak (crying)			
Saç kurutmak (hair drying)			
Yemek (eating)			
Düşmek (falling)			
Balık tutmak (fishing)			
Kesmek (cutting)			
Çamaşır asmak / sermek (hanging clothes)			
Ütü yapmak (ironing)			
Havlamak (barking)			
Dilenmek (begging)			
Örmek (knitting)			
Soymak (peeling)			
Kediyi okşamak / sevmek (patting)			
İtmek (pushing)			
Duş almak / yıkanmak / banyo yapmak (showering)			
Şarkı söylemek (singing)			
Taşımak (carrying)			
Güneşlenmek (sunbathing)			
Islık çalmak (whistling)			
Yırtmak (tearing)			
Süpürmek / süpürge tutmak (sweeping)			
Yazı yazmak (writing)			
Sıkmak (squeezing)			
Hapşırmak / öksürmek (coughing)			
Piyano çalmak (playing piano)			

Toplam bilinen fiil (Total known verb): _____

APPENDIX B

First, stories below were presented to the participants one by one. Once they read the stories, they were asked to explain what they read without looking at the stories. The italic words were considered to be action verbs. Each story included three concrete and three abstract action verbs.

Co-speech Gesture Production Task

1. Aslı yataktan kalktığında güneş *açmıştı*. Babası kardeşiyle inek *sağıyor*, annesi de bahçede çiçek *topluyordu*. Aslı da hiç vakit kaybetmeden üstünü giyinip annesinin yanına *uçtu*, çiçeklerin içine *daldı*. Annesi Ayşe'yi öptükten sonra birbirlerine sıkı sıkı *sarıldılar*.

   (When Aslı woke up, the sun already *rose*. Her father was *milking* the cow with her brother, her mother was *picking* flowers. Aslı wore her clothes without losing time and *flew* next to her mother, *jumped* into the flowers. After her mother kissed Aslı, they *hugged* each other tightly.)

2. Esra işten çıkarken karanlık yeni *çökmüştü*. Çocuklar kurstan dönmeden eve yetişmek istediği için arabaya hızla binip *çalıştırdı*. Tam geri geri çıkarken arabanın biri arkadan Esra'nın arabasına *çarptı*. Duruma çok sinirlenen Esra arabadan *fırladı,* adama sert bir şekilde *çıkıştı*. Adamsa hiç aldırmadan arabasına binip *gitti*.

   (While Esra went out from work, the sky just *got** dark. Since she wanted to catch her kids before they get home from course, she got in her car in rush and *started* the engine. When she was driving the car backwardly, someone *crashed* to her car. She *flew out* from the car, *scolded* to the driver. The man got in his car without caring and *drove away*.)

3. Sahilde oturan bir kadın kitabını okurken bir yandan da yelpazesini *sallıyordu*. Küçük kızları yanında toprağı *kazıyor*, oğlu da denizde *yüzüyordu*. Birden çığlıklar *yükseldi*. Kadın oğlunun çırpındığını görünce yüreği ağzına *geldi*. Görevliler müdahalede bulunup oğlunu kurtarınca üzerinden yük *kalktı*.

(A woman sitting on the beach was reading her book while *waving* her hand-held fan. Her daughters were *digging* the sand near her and her son was *swimming* in the sea. Suddenly, screaming sounds *rose*. When the woman saw her son struggling in the sea, woman's heart *came* to her mouth. When the sea guards interfered and saved her son, burden was *weight off* her shoulder.

4. Mağazada adamın biri kasadaki sırada bir önceki müşterinin önüne *geçti*. Arkasında kalan müşteri sinirlenip adamın omzuna *dokundu* ve sıranın arkasını *işaret etti*. Adam uyarıya aldırmayınca olaylar *patladı*, iki müşteri birbirine *girdi*. Güvenlik müdahale edince herkes kendi işine *döndü*.

   (In a store, while waiting in line, a man *went* ahead in front of the other customer. The customer got mad, *tapped* on his shoulder and *pointed* to the back of the line. When the man did not care his warning, an event *occurred*. Two customers *went up* against each other. When the security interfered, everybody *went back* to their daily lives.)

* Note that because of the translation, some phrases may seem to be concrete (i.e., literal) but in Turkish they have an abstract (i.e., metaphorical) meaning. Additionally, some words may seem not to include action; however, in Turkish they do.

APPENDIX C

In each line, verbs indicated in bold letters are the concrete action verbs presented as options in co-speech gesture comprehension task. We expected participants to find the corresponding action verb by watching the gesture representing a specific concrete action based on the content of the speech.

CO-SPEECH GESTURE COMPREHENSION TASK LIST

LIST (TARGET CONCRETE ACTION VERB)	FILLERS *FROM* THE LIST	FILLERS *NOT FROM* THE LIST
1. Uçak **düştü.** (Plane **fell.**)	**Çıkmak (Exit)**	**Gitmek (Go)**
2. Ekmeği ikiye **ayırdı.** (He **separated** the bread into two.)	**Kesmek (Cut)**	**Dilimlemek (Lice)**
3. Kağıtları **birleştirdi.** (She **gathered** the papers.)	**Ayırmak (Separate)**	**Yırtmak (Tear)**
4. Bıçak elimi **kesti.** (The knife **cut** my hand.)	**Sarmak (Cuddle)**	**Kırpmak (Crop)**
5. Bahçenin duvarından **atladı.** (He **jumped** over the wall.)	**Patlamak (Explode)**	**Koşmak (Run)**
6. Annesi çocuğunu **sardı.** (Mother **cuddled** her child.)	**Yakalamak (Catch)**	**Sarsmak (Shake)**
7. İnsanlar ayağa **kalktı.** (People **stood up**.)	**Geçmek (Pass)**	**İnmek (Descend)**
8. Direksiyonu **çevirdi.** (He **steered** the wheel.)	**Dağılmak (Scatter)**	**Kırılmak (Brake)**
9. Kitaplar her yere **dağıldı** (The books **scattered** everywhere.)	**Düşmek (Fall)**	**Çakılmak (Crash)**
10. Çorbayı **karıştırdı.** (He **stirred** the soup.)	**Koymak (Put)**	**Çalkalamak (Shake)**
11. Hırsızı evde **yakaladı**. (He **caught** the thief at home.)	**Göstermek (Show)**	**Kovalamak (Chaise)**

12. Siparişlerimizi **getirdi.** (He **brought** our orders.)	**Birleştirmek (Gather)**	**Bırakmak (Leave)**
13. Polis evin önünden **geçti** (The police **passed** in front of the house.)	**Kalkmak (Stand Up)**	**Vurmak (Hit)**
14. Ağaçlar **büyüdü.** (The trees **grew**.)	**Çevirmek (Steer)**	**Budamak (Prune)**
15. Cezvedeki süt **taştı.** (The milk **spilled over** the pot.)	**Karıştırmak (Stir)**	**Dolmak (Fill)**
16. Odadan **çıktı.** (She **exited** the room.)	**Taşmak (Spill Over)**	**Girmek (Enter)**
17. Çocuğunu ağaca **çıkardı.** (He **raised** his child up to the tree.)	**Büyümek (Grow)**	**Götürmek (Take Away)**
18. Evdeki borular **patladı.** (The pipes in the house **exploded.)**	**Çıkarmak (Raise)**	**Akmak (Drip)**
19. Yemeğini önüne **koydu.** (She **put** her meal in front of here.)	**Getirmek (Bring)**	**Dökmek (Spill Over)**
20. Yatacakları odayı **gösterdi.** (He **showed** their room.)	**Atlamak (Jump)**	**Süpürmek (Sweep)**

APPENDIX D

In each line, verbs indicated in bold letters are the abstract action verbs presented as options in co-speech gesture comprehension task. We expected participants to find the corresponding action verb by watching the gesture representing a specific abstract action based on the content of the speech.

CO-SPEECH GESTURE COMPREHENSION TASK LIST

LIST (TARGET ABSTRACT ACTION VERB)	FILLERS *FROM* THE LIST	FILLERS *NOT FROM* THE LIST
1. Borsa **düştü.** (Stock market **fell.**)	**Kalktı (Stand Up)**	**Uçtu (Flew)**
2. Arkadaşlar yollarını **ayırdı.** (Friends **separated** their ways.)	**Birleştirmek (Gather)**	**Uzatmak (Extend)**
3. Çiftleri **birleştirdi.** (She **gathered** the couples.)	**Ayırmak (Separate)**	**Yollamak (Send)**
4. Ortağıyla muhabbeti **kesti.** (He **cut** off his relationship with his partner.)	**Sarmak (Cuddle)**	**Silmek (Erase)**
5. Daldan dala **atladı.** (He **jumped** from branch to branch.)	**Düşmek (Fall)**	**Sallanmak (Swing)**
6. *Bu konu beni **sardı.** (This topic **attracted** my attention.)	**Yakalamak (Catch)**	**İtmek (Push)**
7. *Üzerimden yük **kalktı.** (I **got** the load **off** me.)	**Çıkmak (Exit)**	**Gitmek (Go)**
8. *Bir oyunlar **çevirdi.** (He **flipped** games.)	**Karıştırmak (Stir)**	**Oynamak (Play)**
9. Herkes evine **dağıldı.** (Everyone **scattered** to their home.)	**Atlamak (Jump)**	**Çekilmek (Withdraw)**
10. *Ortalığı **karıştırdı.** (He **made** a scene.)	**Göstermek (Show)**	**Temizlemek (Clean Up)**
11. İşin özünü **yakaladı**. (He **captured** the essence of the job.)	**Çıkarmak (Raise)**	**Kaçırdı (Miss)**

12. Yazı çabuk **getirdi.** (He **brought** summer quickly.)	**Kesmek (Cut)**	**Geçirmek (Spend)**
13. Toplantı üç saati **geçti** (The meeting **passed** three hours.)	**Taşmak (Spill Over)**	**Bulmak (Find)**
14. Olaylar **büyüdü.** (Events **grew**.)	**Çevirmek (Stir)**	**Bastırmak (Suppress)**
15. *Kadının sabrı **taştı.** (Woman **lost** her patience.)	**Dağılmak (Scatter)**	**Dolmak (Fill)**
16. *İşten **çıktı.** (She **left** her job.)	**Koymak (Put)**	**Kopmak (Break Off)**
17. *Sinirini çocuktan **çıkardı.** (She **got out** her nerves from her child)	**Patlamak (Explode)**	**Almak (Take)**
18. Öfkesi içinde **patladı.** (Her range **exploded** inside.)	**Büyümek (Grow)**	**Kalmak (Stay)**
19. Söylenilenleri önüne **koydu.** (She **put** what is said in front of her.)	**Geçmek (Pass)**	**Tutmak (Hold)**
20. Ona gerçekleri **gösterdi.** (He **showed** the truths to him.)	**Getirmek (Bring)**	**Sıraladı (Align)**

* Note that some translations are made based on the meaning rather than direct translation. Thus, the verbs written in English may not directly correspond with the Turkish verbs' meaning or may not seem to include action, but in Turkish they do. Also, note that because of the translation, some phrases may seem to be concrete (i.e., literal) but in Turkish they have an abstract (i.e., metaphorical) meaning.