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Original Article

Can compulsions be associated with problems in forming an internal model of the completed state of an action?

Kompulsiyonlar bir eylemin sonlanması durumunda içsel bir model oluşmasındaki problemle ilişkili olabilir mi?

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ABSTRACT

Aim: The aim of this study was to test Obsessive Compulsive Disorder (OCD) is associated with a dysfunctional motor system that cannot appropriately form a forward model of the completed state of an action.

Material and Methods: In three computerized experiments, reaction times to verbs denoting different aspects constituted the main dependent variable. They were conducted to test the hypothesis that patients with OCD would have difficulties in sentences with perfective aspect and/or completed actions and, hence, display longer reaction times to associated stimuli. 40 participants with OCD and 40 non-obsessive controls were included in the study. Experiment 1 was a visual lexical decision task in which participants were instructed to decide on the word/non-word status and, simultaneously, on the temporal reference encoded by stimuli presented on the screen. In Experiment 2, participants had to carry out a number of actions and to rate stimulus sentences that represented either accurate or inaccurate descriptions of the completeness of the actions they themselves carried out. In Experiment 3, participants rated the truth-values of stimulus sentences in relation to the tasks that they had previously carried out in Experiment 2.

Results: Patients with OCD displayed significantly longer reaction times to sentences with actions in the perfective aspect.

Conclusion: The results obtained may be taken as support for the assumption that the feedforward motor control of actions in OCD is problematic.

Keywords: Obsessive compulsive disorder, internal forward models, mental simulation, grammatical aspect, incompleteness

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ÖZ

Amaç: Bu çalışmanın amacı, Obsesif Kompulsif Bozukluğun (OKB) bir hareketi tamamlama durumu için oluşturulan ileriye dönük bir modeli, uygun şekilde oluşturamayacağına yönelik bozuk işlevli bir hareket sistemi ile bağlantılı olduğu hipotezin test edilmesidir.

Gereç veYöntemler: Çalışmada üç bilgisayar deneyi sunulmaktadır. Her üç deneyde de, farkı durumları ifade eden kelimelere reaksiyon zamanları, ana bağımlı değişkeni oluşturmuştur. Deneyler, OKB'li hastaların mükemmeliyetçilik yönü olan cümlelerde ve/veya tamamlanmış hareketlerde zorluklar yaşadıkları ve bu nedenle bağlantılı bir uyarıya daha uzun reaksiyon zamanları gösterdikleri hipotezini test etmek için yürütüldü. OKB'li toplam 40 katılımcı (Deney 1 de 16, Deney 2 ve 3 de 24'er kişi) ve yaş, cinsiyet, ve eğitimleri uyumlu 40 non-obsesif kontrol katılımcı çalışmaya dahil edildi. Deney 1, katılımcının kelime/kelime dışı bir duruma karar verme konusunda talimat verildiği ve eş zamanlı olarak ekrandaki gösterilen uyarı tarafından kodlanmış temporal referansta, kelimelere ait bir karar verme görevi idi. Deney 2'de katılımcılar bir dizi hareketi yerine getirmek ve kendilerinin yaptıkları hareketlerin bütünlüğünün uygun veya uygunsuz olarak tanımlanıp yansıtıldığı uyarı cümlelerini oranlamak zorunda idi. Deney 3'de katılımcılar, Deney 2'de daha önce yaptıkları görevle bağlantılı olarak, uyarı cümlelerinin doğruluk değerlerini oranladılar.

Bulgular: Bulgular bir bütün olarak, OKB'li hastaların kontrol grubu ile karşılaştırıldığında, mükemmeliyetçilik yönü olan hareketlerle ilgili cümlelere daha uzun reaksiyon zamanları gösterdiklerini ortaya koymuştur.

Sonuçlar: Elde edilen bulgular, OKB'da ileri beslemeli hareket denetiminin problemli olduğu varsayımını destekleyici olarak ele alınabilir.

Anahtar Kelimeler: Obsesif kompulsif bozukluk, ileriye dönük içsel model, zihinsel uyarı, gramatik bakış açısı, tamamlanmamışlık.

Introduction

Current pathophysiological models of obsessive-compulsive disorder (OCD) propose a dysregulation of frontal subcortical circuits underlying obsessions and compulsions. This system has been implicated in action monitoring and generates error signals when there is a mismatch between intended and actual performance [1-6]. The term action monitoring refers to the processes of error detection and conflict monitoring during goal-directed responses that are strongly associated with the anterior cingulate cortex (ACC) functioning. Functional imaging and electrophysiology studies have shown ACC hyperactivity in participants with obsessive-compulsive disorder [7-17]. However, the question that has been left unanswered to date is whether the primary problem involved is ACC hyperactivity causing repetitive time consuming compulsions directly or whether ACC hyperactivity is secondary to an internal conflict between components of action execution.

Based on the forward model, in order to complete an action, (i) the predicted representation of consequences of the completed action and (ii) the representation of the intended/expected state of the action (state of completeness) are matched. If the representations of (i) and (ii) match, the action can be completed. On the other hand, if there is a conflict in this matching process, ACC seems to be activated [18,19]. This, in turn, leads to exaggerated action monitoring and a feeling of incompleteness. It therefore follows that if the forward model of the completeness of an action is not well-formed, conflict will inevitably follow. Strict rituals and large numbers of repetitions of actions can therefore be taken as efforts to form a model of completeness.

To the best of our knowledge, no study has tested the assumption that participants with obsessive-compulsive disorder experience difficulty in forming the representation (forward model) of the completeness of an action. The main aim of the present study is therefore to test this assumption. The confirmation of the above assumption could lead to the argument that increased action monitoring is secondary to an internal conflict between components of action execution because of a dysfunctional motor system. Hence, for the present study, a series of experiments was run in order to test the assumption that participants with obsessive-compulsive disorder experience difficulty in creating a forward model of the completeness of an action.

Material and methods

Subjects

A total of 40 participants with obsessive-compulsive disorder (27 women and 13 men) with washing and/or checking compulsions and age (mean age: 27.8, SD: 7.78, range: 19-42), gender and education matched 40 non-obsessive control subjects were included in the study. In line with the main aim of the study of finding an etio-pathogenetic explanation of compulsions, patients without washing and/or checking compulsions were excluded. All participants reported Turkish as their native language and were naïve with regard to the aim of the study. The participants with obsessive-compulsive disorder were recruited between April 2010 and May 2012 from the outpatient clinic of a university psychiatry department. The diagnosis of OCD was established through an extensive clinical interview by a psychiatrist, expert in assessing OCD. The Turkish version of the Structured Clinical Interview for the Diagnosis of Axis I Disorders (SCID-I) [20] was administered to confirm the diagnosis of OCD [21]. The mean duration of the disorder was 9.55 years (SD: 5.77, range: 2.5-236 months). At the time of the present study 82.5% of the patients were on a selective serotonin reuptake inhibitor treatment. The SCID-I was also administered to the control subjects to confirm the absence of any Axis I disorder. The subjects' minimum education level for inclusion in the study was eleven years of schooling. Participants with obsessive-compulsive disorder were excluded if they were diagnosed at the time of the present study with any other DSM Axis I disorder or any neurological or metabolic disorder which could affect experimental performance. The exclusion criteria for control subjects were the presence of any DSM Axis I disorder at the time of or prior to the experiment and any neurological or metabolic disorder which could affect experimental performance. In addition, any subject who reported to be using his/her left hand to carry out the actions of writing, hammering, unlocking doors or using a computer mouse was also excluded from the study.

The Yale–Brown Obsessive–Compulsive Scale (Y-BOCS) [22] was used to determine the global symptom severity of the participants with obsessive-compulsive disorder (mean + Standard Deviation = 22.95 ± 5.64). All participants gave their written informed consent, which was approved by the Local Ethics Committee.

Experiments

Experiment 1

In Experiment 1, 16 participants with obsessive-compulsive disorder and age, sex and education-matched 16 healthy control subjects participated in a simple visual lexical decision task. A total of 60 stimuli, twenty for each suffix, were presented to the participants on a computer screen. Of these stimuli, half were real Turkish words constructed by attaching the above-listed suffixes to an existing verbal stem, while the other half consisted of nonsense words that were formed by attaching the suffixes to non-existing verbal stems. The experimental stimuli were matched for frequency, length and number of syllables. The aim in presenting the subjects with real and nonsense words was to ensure that the subjects did not only focus on the suffixes but took the whole stimulus into consideration.

The subjects were instructed that three predetermined buttons on the keyboard represented the three temporal references of the verbal markers. The subjects were further instructed to wait for the stimulus verb to appear on the screen and press the button that represents the temporal reference of the verb as quickly as possible only if the word that appeared on the screen was a real Turkish word. If the stimulus was a nonsense word, the participants were instructed to wait until a valid word would appear. The time between the appearance of the word on the screen and the button press was taken as the reaction time (RT).

Experiment 2

In Experiment 2, 24 participants with obsessive-compulsive disorder and age, gender and education-matched 24 control subjects performed a total of four tasks. None of the participants in Experiment 2 had also taken part in Experiment 1. The tasks involved the performance of a number of activities on the computer using the mouse and the truth-value evaluation of on-screen sentences that described the actions performed by the participant. The participants were informed that these sentences could appear on the screen (a) while they were actually performing the related task or (b) at the very end (Figure 1). The participants were asked to decide whether these sentences represented accurate descriptions of the action(s) they would be/had been performing as part of the task and to press the corresponding predetermined button on the keyboard as quickly as possible. The participants were explicitly told that they were eventually going to complete each task, even if the sentences should appear in the middle of performing a task. A practice task was run before the actual experimental tasks.

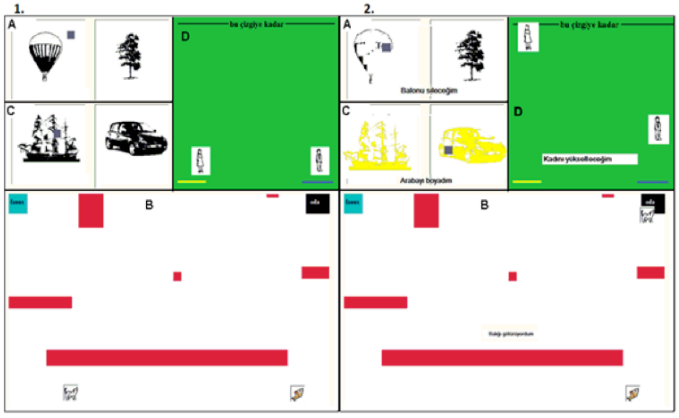

Figure 1. 1. displays the starting point of the tasks (A, erasing; B, moving; C, painting; D, elevating) and 2. displays the state of the tasks that sentences were presented.

The purpose of Experiment 2 was to form mental models (representations) of actions with different states (completed/uncompleted) in the participants' minds. In addition, reaction time (RT), which was the time between the appearance of the sentence and the pressing of the button, was measured. According to the hypothesis that participants with obsessive-compulsive disorder have difficulty in forming the mental representation of the completed state of an action, the RTs of participants with obsessive-compulsive disorder to completed tasks were expected to be longer in comparison to those of controls. The second experiment also provided an online observation of the ability to form the mental representation of the state of an action.

Experiment 3

Experiment 3 was administered immediately after Experiment 2 and involved the same 48 subjects. In this experiment, the participants were presented with 9 sentences for each of the tasks that they had performed in Experiment 2. Out of these 9 sentences, only 4 were actually experimental items (2 prospective, 2 perfective), while the remaining 5 sentences acted as fillers. The subjects were asked to decide on the truth-value of these sentences in relation to the tasks that they had carried out in Experiment 2 and to press the corresponding button on the keyboard as quickly as possible. RT, which was the time between the appearance of the sentence and the pressing of the button, was the main dependent variable.

Results

The data collected in Experiment 1 was analysed by means of a Repeated Measures ANOVA. The results of a Repeated Measures ANOVA revealed main effects of neither group ($F[1, 30] = 0.046$, $P = 0.832$, $ES = 0.002$) nor aspect ($F[1, 30] = 1.009$, $P = 0.323$, $ES = 0.033$) but a significant group * aspect ($F[1, 30] = 5.336$, $P = 0.028$, $ES = 0.151$) interaction.

While the participants were carrying out a given task, a text box appeared at the time points described in Table 1 that presented sentences a-c separately and in consecutive order. These sentences were constructed with three grammatical structures (perfective aspect, imperfective aspect and prospective aspect). The participants decided on the truth-value of each sentence and pressed the related button as quickly as possible. This was immediately followed by the next task.

Table 1. Details of experimental materials used in Experiment 2.

	Action	**Object 1**	**Object 2**		Sentences to be evaluated
Task 1	erasing	balloon	tree	While erasing Object 1 (the balloon). -Parts of Object 1 (the balloon) were erased already. -Object 2 (the tree) was not erased at all.	a) Balonu sileceğim (I will erase the balloon) b) Ağacı sildim (I erased the tree) c) Balonu siliyordum (I was erasing the balloon)
Task 2	moving	dog	fish	After having moved Object 1 (the dog) to the room. -Object 2 (the fish) had not been moved yet.	a) Balığı götürüyordum (I was moving the fish) b) Köpeği götürdüm (I moved the dog) c) Balığı götüreceğim (I will move the fish)
Task 3	painting	car	ship	After having painted Object 1 (the car). -Both Object 1(the car) and Object 2 (the ship) were completely painted.	a) Arabayı boyadım (I painted the car) b) Gemiyi boyayacağım (I will paint the ship) c) Arabayı boyuyordum (I was painting the car)
Task 4	elevating	man	woman	While elevating Object 1 (the man). -Object 2 (the woman) was already elevated to the top of the screen.	a) Kadını yükselttim (I elevated the man) b) Kadını yükselteceğim (I will elevate the woman) c) Adamı yükseltiyordum (I was elevating the man)

The RTs of participants with obsessive-compulsive disorder to verbs inflected with the perfective aspect marker were markedly higher than their RTs to stimuli in the prospective aspect, whereas the control subjects' RTs displayed no such difference. Table 2 shows the mean RTs (in milliseconds, ms), standard deviations (SD) and confidence intervals (CI) of the groups for perfective and prospective stimuli in Experiment 1.

Table 2. Mean RTs (in milliseconds, ms), standard deviations (SD) and confidence intervals (CI) of the groups for perfective and prospective stimuli in Experiment 1.

Group	Aspect	Mean RT (in ms)	SD	N (Number of trials)	%95 CI (Lower bound)	%95 CI (Upper bound)
Control	perfective	795.6	129.3	16	730.3	860.9
	prospective	828.1	115.7	16	769.4	886.9
OCD	perfective	845.6	126.5	16	780.3	910.9
		763.1	114.6	16	704.4	821.9

The ANOVA in Experiment 2 revealed significant main effects for group (F[1,232]= 9.676, P = 0.002, ES=0.040) and SoAc (F[1,232] = 6.184, P = 0.014, ES = 0.026) and interaction effects for aspect *SoAc (F[1,232] = 6.089, P = 0.014, ES =0.026) and group * aspect *SoAc (F[1,232] = 6.235, P = 0.013, ES = 0.026). Accordingly, the OCD group was overall slower in responding to uncompleted actions. In other words, the conflict between aspect and SoAc led to longer RTs. The RTs of participants with obsessive-compulsive disorder were longer if a sentence describing an action that the subject had not yet completed included a verb in the perfective aspect (i.e. "I elevated the man"). There was no significant main effect of aspect (F[1,232] = 0.585, P = 0.445, ES = 0.003), and no significant group * aspect (F[1,232] = 2.377, P = 0.124, ES = 0.010) or group *SoAC (F[1,232] = 2.909, P = 0.089, ES = 0.012) interactions. Table 3 displays the mean RTs, SDs and 95% confidence intervals(CI) of groups by aspect and SoAc.

Table 3. Mean RTs (in milliseconds, ms), standard deviations (SD) and confidence intervals(CI) of participant groups according to state of action (SoAc) (completed or incompleted) and aspect of the stimuli (perfective or prospective) in Experiment 2.

Group	Aspect	SoAc	Mean RT (in ms)	SD	N (Number of trials)	%95 CI (Lower bound)	%95 CI (Upper bound)
(in ms)	perfective	incomplete	932.1	458.2	19	674.9	1189.3
		complete	871.4	473.7	43	1357.8	1936.8
	prospective	incomplete	997.2	382.6	18	700.4	1042.4
		complete	931.8	312.7	40	738.7	1076.8
OCD	perfective	incomplete	1647.3	1348.7	15	732.9	1261.5
		complete	907.7	398.1	44	802.8	1317.2
	prospective	incomplete	1060.0	355.2	19	754.5	1109.0
		complete	1122.4	717.1	42	949.4	1295.4

The results of the ANOVA in Experiment 3 revealed main effects of group (F[1,417] = 15.496, P < 0.001, ES = 0.036) and aspect (F[1,417] = 8.746, P = 0.003, ES = 0.021). These results show that the OCD group was significantly slower than the control group and that subjects had significantly shorter RTs to the perfective aspect in comparison to the prospective aspect. The results further revealed a significant aspect *SoAc interaction (F[1,417] = 5.522, P = 0.019, ES = 0.013). When aspect and SoAc were in conflict (i.e., in sentences constructed with the prospective aspect, associated with a completed task), the RTs were found to be longer. There was no significant main effect of state of action (F[1,417] = 2.779, P = 0.096, ES = 0.007). Furthermore, there were no further significant interactions (group * aspect F [1,417] = 0.095, P = 0.758, ES = 0.000; group *SoAcF [1,417] = 1.515, P = 0.219, ES = 0.004; group * aspect *SoAcF [1,417] = 0.001, P = 0.970, ES = 0.000). Table 4 displays the mean RTs, SDs and 95%CIs of groups by aspect and SoAc.

Table 4. Mean RTs (in milliseconds, ms), standard deviations (SD) and confidence intervals (CI) of groups according to state of action (SoAc) (completed or incompleted) and aspect of the stimuli (perfective or prospective) in Experiment 3.

Group	Aspect	SoAc	Mean RT (in ms)	SD	N (Number of trials)	%95 CI (Lower bound)	%95 CI (Upper bound)
Control	perfective	incomplete	1147.0	648.7	40	942.0	1352.0
		complete	950.0	484.4	78	1285.8	1767.4
	prospective	incomplete	1208.3	443.9	36	803.2	1096.8
		complete	1344.5	620.9	69	1013.2	1312.7
OCD	perfective	incomplete	1526.6	814.6	29	992.2	1424.5
		complete	1162.9	562.3	75	1300.4	1799.6
	prospective	incomplete	1550.0	788.3	27	1188.4	1500.6
			1509.2	892.5	71	1355.3	1663.1

Discussion

The aim of this study was to test the hypothesis that OCD is a disorder associated with a dysfunctional motor system that cannot appropriately form a forward model of the completed state of an action. In order to test this hypothesis, a series of experiments was conducted with participants with obsessive-compulsive disorder with washing and/or checking compulsions and their age, sex and education-matched non-OCD controls. In the experiments, the aim was to form mental models of different states of actions. It was hypothesized that participants with obsessive-compulsive disorder would display differences, especially in the completed states, observable in the form of longer RTs.

Experiment 1 was designed based on the findings that motor and perceptual systems are activated not only for action execution but also for the understanding of the content of a sentence (so-called mental simulations). Thus, if the motor system of a participant with obsessive-compulsive disorder is unable to complete an action, the same system should also be unable to mentally simulate a sentence signaling the completeness of an action. As hypothesized, the results revealed a significant group * aspect interaction, which indicated that participants with obsessive-compulsive disorder had longer RTs in reaction to stimuli in the perfective aspect in comparison to those in the prospective aspect, which was not observed in the control group.

In Experiment 2, a significant group * aspect *SoAc interaction was observed. Thus, when the participants with obsessive-compulsive disorder did not complete the action, they displayed higher reaction times to sentences that contained the verb in question in the perfective aspect. In other words, Experiment 2 also indicated that perfective aspect causes slower responses in the OCD group. Based on the repeated findings that participants with obsessive-compulsive disorder have difficulties in resolving conflict situations [23-25] the finding can be interpreted as a consequence of the sensitivity of participants with obsessive-compulsive disorder to the conflict that existed between the aspect (perfective) and SoAc (uncompleted). However, as can be seen in Figure 2, the effect of the conflict did not cause a symmetric effect as the difference was visible only under the effect of perfective aspect in the OCD group. Thus it can be concluded that the participants with obsessive-compulsive disorder have difficulty in processing perfective aspect. Based on the neurolinguistics literature, the motor and perceptual systems dedicated to perform an action are activated when comprehending the linguistic expression of this action. The same can also be expected for the processing of aspect; that is, the mental model of the state of an action plays a role while comprehending and/or producing the aspect. As a conclusion, the first and second experiments of the present study support the hypothesis that participants with obsessive-compulsive disorder may have a problem in forming the mental representation (the forward model) of the completed state of an action.

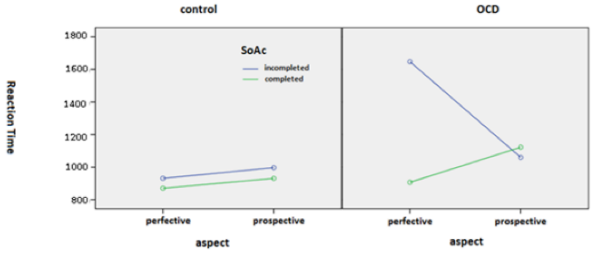

Figure 2. Graphic of the significant group X SoAc X Aspect interaction in the experiment two.

It has been thought that OCD symptoms result from a dysfunctioning of the ability to determine the stopping/ending point of a given action. Supportively, in the study of Zor et al, the compulsive behaviors of participants with obsessive-compulsive disorder were evaluated according to functional and non-functional acts in the compulsive rituals and non-functional acts were more frequently observed in OCD groups than in non-OCD subjects in the last zone of the behavior package or compulsive rituals [26]. Although the completing problem of participants with obsessive-compulsive disorder has been mentioned several times in the literature, mental models of the motor control of completing compulsive acts have not been focused on directly. To our knowledge, there is only one study assessing the internal forward model in OCD. The researchers of this study focused on the agency dimension of an action and reported findings indicative of a dysfunctional forward model [27].

Additionally, in Experiment 3, no significant result associated with the independent variable "group" was obtained, with the exception of the main effect of group. Even the significant group * aspect *SoAc interaction, which was observed in Experiment 2, disappeared. This directs us to think that the complexity of the experiments increased in the sense that more cognitive resources were required in Experiment 3, which resulted in a decrease in the observable effect of the forward model. It should be admitted that the effect of a dysfunctional motor system is not the only problem that causes compulsions and that such a deficit is part of a complex cognitive control deficit. There is a huge literature supporting the idea that OCD is a general cognitive control system disease. The results of this study direct us to consider that the problem belongs to the motor system and its forward control in future studies [28-31].

Declaration of conflicting interests

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