# Short-Term Transfer Effects of Tetris on Mental Rotation: Review and Registered Report – A Bayesian Approach

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**Abstract**

The existence of transfer effects of video games on cognitive performance are controversially discussed in experimental psychology. Whereas recent meta-analyses suggest the absence of far transfer effects, empirical evidence regarding near transfer effects is more controversial. This conceptual replication investigated the short-term near transfer effect of playing Tetris on mental rotation abilities. The design of the conceptual replication was based on a comprehensive compilation of the methods used by previous literature on this topic and advanced in order to reach a high scientific state-of-the-art standard. We ran a high-powered conceptual replication study with ***X*** participants ***[Note: X will be replaced by the number of participants after data collection has been completed]*** randomly assigned to either an experimental group playing Tetris or a control group playing Solitaire. Both groups completed three commonly used mental rotation tests in a pre- and a posttest-session. Additionally, the experimental group played Tetris while the control group played Solitaire. Gaming time was 10 hours in total within 4 weeks. Based on previous research, we hypothesized that this might generate a short-term transfer effect of Tetris on mental rotation. ***Results and conclusion will be added to the abstract after data collection and analysis have been completed.***

*Keywords:* transfer effect, video games, mental rotation, Tetris, Bayes

## Background

Video games are among the most popular and frequent leisure time activities in today's culture. Since the beginning of video game usage, researchers have been interested in the cognitive effects of gaming. A generalized transfer effect of video games on cognitive performance is a controversially discussed topic in experimental psychology (Bediou et al., 2018). There is a wide range of research in this field with different findings but recent meta-analyses proposed that there are no reliable far and long-term transfer effects of video games and that there are also contradictory findings regarding the existence of short-term near transfer effects of video game play (Meneghetti et al., 2016, 2018; Moreau, 2013; Quaiser-Pohl et al., 2006; Sala et al., 2018). With the present study, we want to contribute to this discussion by the publication of a data set that is unbiased by its statistical significance. Thus, we focused on and conducted a registered conceptual replication report of the short-term transfer effect of playing Tetris on mental rotation abilities, which is one of the most used and cited short-term near transfer effects (e.g. Boot et al., 2008; Green & Bavelier, 2003; Nouchi et al., 2012). We investigated the theory of the specific transfer of general skills (as described in Sims and Mayer, 2002 and Pilegard & Mayer, 2018), which states that learning a skill in a game will transfer to performance on the same skill in another venue outside the same.

In order to ensure a comprehensible conceptual replication, we searched with the keywords Tetris, training, game, mental rotation, transfer and/or effect in PsycARTICLES, PsycINFO, PSYNDEX and grey literature. Twenty-seven studies were included in the first step. In the second step, we excluded all studies that did not directly relate Tetris to mental rotation, did not have a control group, did not manipulate solely training of Tetris or that did not specify sample characteristics or experimental procedure. Thus, we finally included eight studies into the present review and into the conceptual replication. This research used at least one of three common mental rotation tests (see Table 1) and was published within the period from 1994 to 2018 (see Table 2). Taking a closer look into the literature, however, the measured variables and effects differ heavily across studies.

**Table 1. Common Mental Rotation Tests**

| Test | Dimension | Items | Maximum Points | Task |
|---|---|---|---|---|
| Card Rotations Test (CRT) | 2D | 20 | 160 (80[1]) (39[2]) | Participants have to detect if a rotated card is the same as or different from the reference shape (referred to as card). Each item has a reference card on the left and eight test cards on the right. Participants have to choose for every card if it is the same or a different card compared to their reference card. Participants have six minutes for this test. One point per card is given. If one card is interpreted falsely, a negative point is given and subtracted from general score (Ekstrom et al., 1976) |
| Cube Comparisons Test (CCT) | 3D | 42 | 42 | Participants have to detect if a rotated cube is the same as or different from the reference shape (referred to as cube). Each item has a reference cube on the left and a test cube on the right. Participants have to choose for the test cube if it is the same or a different cube compared to their reference cube. Participants have six minutes for this test. One point per cube is given. If one cube is interpreted falsely, a negative point is given and subtracted from general score (Ekstrom et al., 1976). |
| Mental Rotation Tests (MRT) | 3D | 20/24 | 20/24 (40[3]) | Participants see a Tetris-block-like reference shape and have to detect the two rotated versions from four alternatives. Participants have six minutes for this test. For each item, one point was given if participants correctly indicated the two rotated alternatives and no false alternative. There are no negative points (Peters et al., 1995; Vandenberg & Kuse, 1978). |

[1] Sims & Mayer (2002), Pilegard & Mayer (2018), [2] De Lisi & Wolford (2002), [3] De Lisi & Cammarano (1996)

In the following three paragraphs, we present the mental rotation tests used including the transfer effects found in comparison, varying gender effects across studies, as well as experimental procedures. One major difference between studies in this field is the measurement of mental rotation abilities. Three different tests are used commonly (see Table 1), but different patterns were found with these tests. In one of the first studies investigating the effect of Tetris on mental rotation, playing Tetris improved reaction time regarding mental rotation and led to higher scores

**Table 2. Studies Investigating Short-Term Transfer of Tetris on Mental Rotation Characteristics (Ordered Chronologically)**

| Study | Mental Rotation Test* | Learning Outcomes Reported | Transfer Effects *(TE)* by Gender | Sample Size | Training Duration | Control Condition (CC) |
|---|---|---|---|---|---|---|
| Okagaki & Frensch (1994) | CRT, CCT & MRT (modified) | Playing Tetris improved mental rotation skills (CCT & MRT only) | Mixed findings | N = 57 | 6h (12 x 0.5h, within 2 weeks) | Non-active CC |
| De Lisi & Cammarano (1996) | MRT | Playing Tetris improved mental rotation skills | Stronger TE for males | N = 110 | 1h (2 x 0.5h, 1 week between) | CC played Solitaire (strategic card video game) |
| Sims & Mayer (2002) | CRT & MRT (modified) | Playing Tetris did not improve mental rotation skills compared to a matched control group | Female participants only | N = 16 | 12,3h (1 x 20min + 12 x 1h, within 4 weeks) | Non-active CC |
| De Lisi & Wolford (2002) | CRT (modified) | Playing Tetris improved mental rotation skills | Mixed findings | N = 47 | 5,5h (11 x 0.5h, within 4 weeks) | CC played Carmen San Diego (educational mystery video game) |
| Cherney (2008) | CRT & MRT | Playing Tetris improved mental rotation skills | Stronger TE for females | N = 61 | 4h (0.5h + 3 x 1h + 0.5h, within 1 or 2 weeks) | CC solved Puzzle (real world) |
| Terlecki et al. (2008) | MRT | Playing Tetris did not improve mental rotation skills compared to a matched control group | Mixed findings | N = 180 | 12h (12 x 1h, within 12 weeks) | CC played Solitaire (strategic card video game) |
| Boot et al. (2008) | MRT (modified) | Playing Tetris improved mental rotation skills | Not reported | N = 82 | 21.5h (Session duration not reported, 4-5 weeks) | CC played either Medal of Honor, Rise of Nations, or was non-active |
| Pilegard & Mayer (2018) | CRT | Playing Tetris did not improve mental rotation skills compared to a matched control group | Not reported | N = 66 (n = 49: 2 Tetris groups) | 4h (4 x 1h + pretest, within 5 weeks) | Non-active CC |

*Note.* *The column mental rotation test includes only standardized mental rotation tests used in the respective study.

on the CCT (Okagaki & Frensch, 1994). For the CRT, they did not observe any training effect that was specific to Tetris (Okagaki & Frensch, 1994). However, eight to nine year old children improved their mental rotation skills on the CRT if they performed below average before (De Lisi & Wolford, 2002).

Cherney (2008) reported improved CRT scores caused by Tetris. However, this study failed to report the interaction with the game played (Tetris vs. control). Instead, the control group also showed a significant improvement in CRT leaving open the possibility that there was only a repeated testing improvement for the CRT instead of a training effect that was specific to Tetris. Sims and Mayer (2002) found no specific transfer effect of Tetris on the CRT but a repeated testing effect as well. Using the MRT, small to moderate short-term transfer effects of Tetris were reported (De Lisi & Cammarano, 1996; Terlecki et al., 2008). However, the transfer of Tetris and action video games regarding mental rotation seem to be comparable (Cherney, 2008). Furthermore, it seems surprising, that participants improved more on 3D measures (MRT) than on 2D measures (CRT) of mental rotation considering that Tetris trains 2D rotations rather than 3D rotations. To summarize, these mental rotation tests show different outcomes in different experimental sets and this might be a first hint that short-term near transfer effects of Tetris on mental rotation are not as robust as sometimes described (see Table 2).

These eight studies do not differ only with regard to the reported transfer effects for different measures of mental rotation abilities, but there are also varying gender effects (see Table 2). These gender differences across the mental rotation tests reported are not consistent, sometimes favoring a better transfer effect in males (De Lisi & Cammarano, 1996; Okagaki & Frensch, 1994) but sometimes the other way round (Cherney, 2008). This might provide another indication that short-term transfer effects of Tetris on mental rotation are not as robust as sometimes reported.

Another major difference across these studies is the experimental procedure including the training duration, sample size and control condition as shown in Table 2. Sample size ranged from 16 to 180 across studies. Within eight studies, there were five different control group conditions. Only Solitaire (De Lisi & Cammarano, 1996; Terlecki et al., 2008) and not playing any game (Okagaki & Frensch, 1994; Pilegard & Mayer, 2018; Sims & Mayer, 2002) were used more than once. Furthermore, the duration of both the whole experiment (1 to 12 weeks) and individual sessions (20 to 60 minutes) differed a lot.

All in all, the results and procedures of the studies reported, deliver contradictory conclusions. As there are various methodological variations across the studies reported, we performed a conceptual replication based on a comprehensive compilation of the methods used by previous literature rather than a precise replication of a particular study in order to strike a balance between the different studies, which found evidence either for or against a short-term transfer effect induced by practicing Tetris.

The replication of the effect of Tetris on mental rotation abilities is not only interesting in itself. Rather, it has a strong impact on the debate about the existence of short-term game transfer effects in general because it is one of the nearest transfer effects in gaming literature. If this effect cannot be replicated consistently, eventually other near game transfer effects have to be questioned, too, as they might have another base than a sole game transfer effect. There are many advantages of this registered replication, which can have a strong impact on future research. First, this study is highly powered, unbiased by statistical significance and was peer reviewed prior to the publication in order to maximize objectivity. Second, we used the Bayesian statistics framework. Thus, we can draw a conclusion about a transfer effect independently of the presence or absence of the effect, in detail we are able make a decision favoring the Null or the alternative hypothesis, which stands in contrast to all former published NHST papers in this field. Third, we give a summary about previous research regarding this topic and provide differences and commonalities, which result in a well-considered method. In accordance to the AP&P RRR guide, we state that there are no previous, related experiments, published or unpublished, conducted by the authors regarding this subject.

## Methods

We matched the methods in the light of consensus in the field, namely an efficacy study as proposed by Green and colleagues (2019).

*Participants.* Given the huge variability in effect sizes in literature (Boot et al., 2008; Cherney, 2008; De Lisi & Cammarano, 1996; De Lisi & Wolford, 2002; Okagaki & Frensch, 1994; Pilegard & Mayer, 2018; Sims & Mayer, 2002; Terlecki et al., 2008), we calculated a Bayes Factor Design Analysis (BFDA) for a sequential design and two-sided Bayesian *t*-test assuming a medium effect size of d = 0.5, a prior as zero-centered Cauchy distribution with a scale parameter of $\sqrt{2}/2$, asymmetric Bayes Factor boundaries of 1/6 and 10, and a minimum sample size of 50 participants per group (Schönbrodt & Wagenmakers, 2018). In order to achieve a conclusion rate of .8, we would need to collect 176 participants per group under the assumption that the H0 is true and 106 participants per group under the assumption that the H1 is true. Following our BFDA, we decided to recruit a minimum of 50 participants per group and a maximum of 176 participants per group and to apply an optional stopping rule once any of the two Bayes Factor boundaries are reached for each of the mental rotation tests investigated while the balance across conditions is not violated. This left us with a probability of .968 for true positive evidence, .002 for false negative evidence, and .03 for inconclusive evidence under the assumption of a true effect of 0.5 and a probability of .788 for true negative evidence, .017 for false positive evidence, and .196 for inconclusive evidence under the assumption of no effect. Following these rules, we collected the data of ***X*** participants (males and females were equally distributed across groups). Participants were paid 5€ for the first session and 5€ for the last session while the gaming time was promoted with a lottery drawing of shopping vouchers (10 x 100€ and 20 x 50€). The BFDA script and the simulated data can be found here: https://osf.io/d3wuc/

*Materials.* The game used in the experimental group was Tetris. The control group played Solitaire. We measured mental rotation abilities with the three commonly used rotation tests, in detail CRT, CCT and MRT (see Table 1). This study was conducted online. Therefore, we presented electronic versions of the mental rotations test. Furthermore, we measured participants' expectations regarding the influence of playing Tetris and Solitaire on mental rotation performance (Boot et al., 2013)[1]. We measured expectations before game exposure in order to avoid confounding factors due to the manipulations.

*Procedure*. The procedure applied was based on a comprehensive compilation of the methods used by previous literature rather than a precise replication of a particular study in order to strike a balance between the different studies, which found evidence either for or against a short-term transfer effect induced by practicing Tetris. Mental rotation tests were taken twice, as pre- and posttest. The order of the three mental rotation tests was balanced across participants and applied to pre- and posttest. In the beginning, we measured the expected outcomes within a

[1] In order to mask our interest in those two particular items, we measured them within a questionnaire asking about the expected influence of four games (Tetris, Solitaire, FIFA, Grand Theft Auto [GTA]) regarding four abilities (mental rotation, memory performance, visual attention, calculation) on a rating scale ranging from 1 (strongly agree) to 4 (strongly disagree) with a random order of questions for each participant.

masked questionnaire including questions about the effect of Tetris and Solitaire on mental rotation abilities. After completing the pretest, participants were asked to play for ten hours in a self-paced manner within a maximum of 4 weeks and a maximum playing time of 2 hours per day (actual playing times logged by our online platform to ensure the intended practice times). The experimental group played Tetris and the control group played Solitaire. After ten hours of game practice, the posttest was taken.

*Analysis.* In order to ensure that all participants entering our analysis were engaged in Tetris, we replaced any participant that played less than ten hours within 4 weeks. We increased logged playing time only whenever there was an activity every 15 seconds for Tetris and 60 seconds for Solitaire. We first computed the pre-post difference score for each mental rotation test and participant. The pre-post difference is calculated to control for a lone repeated testing effect. Thus, we can interpret the improvements regarding video game practice. Thereafter, we compared those difference scores across our games (Tetris vs. Solitaire) using two-sided Bayesian *t*-tests with the same prior as in the design analysis. This Bayesian approach lets us evaluate the strength of evidence in favor of either the H0 (no transfer of game play on mental rotation abilities) or the H1 (playing Tetris affects mental rotation abilities). We ran these Bayesian *t*-tests for each mental rotation test individually because we expected potentially contradictory results between the different mental rotation tests based on previous research. Despite our main interest being concerned with the existence of an overall transfer effect of playing Tetris on mental rotation abilities, we ran three additional Bayesian ANOVAs including the factors game (Tetris vs. Solitaire) and gender (male vs. female) in order to investigate potential gender effects within our sample as well as Bayesian ANCOVAs including expected outcomes regarding mental rotation abilities. We made the data publically accessible on OSF: https://osf.io/d3wuc/

## Results

## General discussion

## Open Practices Statement

The data and materials for this registered report are available at https://osf.io/d3wuc/

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