Testing the Two-Factor Model of Musical Obsessions: Can They Be Predicted by the Interaction Between Frequency and Dysfunctional Interpretations of Common Earworms?

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Abstract
Musical obsessions can be conceptualized as a severe form of intrusive musical imagery (IMI). The two-factor model of musical obsessions proposes that musical obsessions result from the interaction of the frequency of IMI and dysfunctional interpretations of IMI. The aim of this study was to evaluate the predictions of the two-factor model. A total of 372 participants (291 without a known diagnosis of obsessive–compulsive disorder [OCD] and 81 with a lifetime diagnosis of OCD) completed online questionnaires about the frequency of IMI, their dysfunctional interpretations, and their severity. We specified a model with severity of IMI as outcome and interpretations and frequency as predictors and controlled for the type of sample. The interaction between frequency and dysfunctional interpretations predicted severity of IMI, however in another direction than suggested. Future studies should include experimental and longitudinal designs and pay particular attention to low-frequency IMI and their role in musical obsessions.

Keywords Obsessive–compulsive disorder · Musical obsessions · Intrusive musical imagery

The experience of hearing recurrent fragments of music in the absence of an external source is common and colloquially known as an earworm (Williams, 2015). Scientifically, these involuntary auditory cognitions are described as intrusive musical imagery (IMI; Taylor et al., 2014). Recurrent IMI can take many forms: a complete piece of music or short sequences, a verse or a refrain, a pop song or classical music, a children’s song or an advertising jingle, a vocal or an instrumental piece (Beaman & Williams, 2010), and it can also include nonmusical auditory experiences such

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as the ring of a smartphone (Beaman, 2018; Taylor et al., 2014). Ninety percent of individuals in an internet survey experienced recurrent IMI at least once a week (Liikkanen, 2012). The frequency of recurrent IMI is positively related to the degree of musical involvement of the person, including time spent listening to music, practicing an instrument (Beaman & Williams, 2010; Floridou et al., 2015; Liikkanen, 2012), or singing (Williamson & Müllensiefen, 2012), and the degree of musical training (Liikkanen, 2012).

While the majority of IMI episodes are experienced as pleasant or neutral (Beaman & Williams, 2010; Halpern & Bartlett, 2011) and typically result in enjoyment or passive acceptance (Williamson et al., 2014), approximately 25 to 30% of episodes are considered annoying or unpleasant (Beaman & Williams, 2010; Liikkanen, 2012). Often individuals develop strategies to stop or reduce unwanted IMI, including active resistance (Liikkanen et al., 2015), distraction with musical (e.g., listening to a “cure” piece of music) or nonmusical (e.g., conversing, reading) activities, engagement with the IMI, such as finding and listening to the complete piece of music (Beaman & Williams, 2010; Williamson et al., 2014), or attempts at IMI suppression (Beaman, 2018). While some authors have discussed the futility or even paradoxical effects of such attempts (Beaman, 2018), others have reported that these strategies are effective in reducing the IMI (Williamson et al., 2014). Beaman and Williams (2010) found that in 11% of their participants, recurrent IMI stopped them from doing other things. In extreme cases, recurrent IMI and responses to IMI can result in substantial distress and social, work-related, or other functional impairments (Rafin, 2016; Taylor et al., 2014).

The intrusive nature of recurrent IMI has led some researchers to draw similarities to obsessions (Levitin, 2007; Sacks, 2007), since obsessions are also intrusive and recurrent (American Psychiatric Association, 2013). In line with these assumptions, positive associations between the frequency of IMI (Williamson & Müllensiefen, 2012) or the disturbance and interference caused by recurrent IMI (Floridou et al., 2015; Muellerensiefen et al., 2014; Williamson & Müllensiefen, 2012) and obsessive–compulsive symptoms have been found. However, because of the predominantly positive experience associated with IMI, which contrasts with the unwanted and distressing nature of obsessions, Beaman and Williams (2010) have argued that obsessions and recurrent IMI are associated because of the similarities in responses, such as attempts at thought suppression, rather than shared characteristics or origins. More recently, impairing or distressing forms of recurrent IMI have been conceptualized as extreme forms of IMI that can be considered a subtype of obsessions. Musical obsessions are defined as recurrent IMI that also meet criteria for non-music-specific obsessions; that is, the IMI is persistent, recurrent, and time-consuming (more than 1 h/day), and causes distress or functional impairment (Taylor et al., 2014). This assumption builds on the idea that recurrent IMI and musical obsessions lie on a continuum. One end is characterized by intrusive but pleasant fragments of recurring music, such as the IMI that nearly everybody occasionally experiences, and the other end is characterized by extreme forms of frequent and distressing IMI, such as musical obsessions. In between lie experiences such as slightly or occasionally annoying IMI.
Systematic research into the phenomenology, etiology, and treatment of musical obsessions has only just begun, and there is a lack of empirical tests of theoretical accounts of recurrent IMI. There have been no epidemiological studies and the prevalence rate is unknown. Taylor et al. (2014) estimated that musical obsessions are rare but that the prevalence might be underestimated because of a lack of adequate measures to assess them. Case reports (Alexander et al., 2019; Euser et al., 2016; Hemming & Altenmüller, 2012; Manuel Orjuela-Rojas & Lizarazo Rodriguez, 2018; Rafin, 2016; Yoshimura et al., 2021) and a review by Taylor et al. (2014) suggested that musical obsessions, similar to recurrent IMI, consist of short fragments of music or other verbal (e.g., lyrics of a poem) or auditory (e.g., alarm tones of smartphones) materials that occur intermittently or continuously and can last for minutes or several hours a day. Various situations have been reported to bring about the onset of the musical obsessions, including spending a lot of time listening to music and experiencing periods of stress, such as studying for exams (Taylor et al., 2014). Importantly, musical obsessions cause significant interference and impairment, including insomnia (Hemming & Altenmüller, 2012; Manuel Orjuela-Rojas & Lizarazo Rodriguez, 2018) and the inability to follow conversations (Manuel Orjuela-Rojas & Lizarazo Rodriguez, 2018; Yoshimura et al., 2021) or concentrate on schoolwork (Rafin, 2016; Yoshimura et al., 2021). Additionally, a variety of responses to musical obsessions, similar to those for recurrent IMI, have been reported, such as attempts to resist the musical obsessions and avoid situations that might trigger them, attempts at suppression, listening to other music, and listening to the end of the same song that is recurring (Hemming & Altenmüller, 2012; Manuel Orjuela-Rojas & Lizarazo Rodriguez, 2018; Taylor et al., 2014).

Taylor et al. (2014) suggested that the interaction between two factors can explain musical obsessions: (a) interindividual differences in the frequency and persistence of IMI, and (b) dysfunctional interpretations of common IMI. They argued that infrequent IMI is unlikely to result in dysfunctional interpretations since, in contrast to obsessions, the content of IMI is per se not distressing. Consequently, in their view, neither dysfunctional interpretations alone nor frequency alone can explain the development of musical obsessions, but their interaction can. The two-factor model is a modification of the cognitive model of obsessions (e.g., Rachman, 1997, 1998) that stresses the causal role of threatening misinterpretations of unwanted intrusive thoughts in the maintenance and development of OCD. Taylor et al. (2014) extended the cognitive model using the assumption that only if IMI is frequent is it likely to be misinterpreted and to become distressing. If frequent IMI is, for example, misinterpreted as a sign of losing control or as interfering with exam preparations, then this naturally occurring IMI is likely to transform into a distressing form of IMI such as musical obsession. If, on the other hand, frequent IMI is interpreted as an innocuous background soundtrack, then it is unlikely to be experienced as distressing.

The primary aim of this study was to evaluate the predictions of the two-factor model of musical obsessions for the first time using a cross-sectional study design. We hypothesized that the severity of IMI is particularly high if dysfunctional interpretation and frequency of IMI are both elevated, thus suggesting an interaction effect between frequency and interpretations of IMI when predicting severity of IMI. As a secondary aim, we sought to determine the self-reported frequency of
distressing and functionally impairing IMI that is likely to meet criteria for obsessions according to the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM-5; American Psychiatric Association, 2013).

**Materials and Methods**

**Participants**

Assuming that recurrent IMI and musical obsessions lie on a continuum and that distressing IMI is associated with obsessive–compulsive symptoms, we aimed to cover a broad range of severity of IMI in our sample by including individuals with and without OCD. Individuals without a known diagnosis of OCD (n = 291) were recruited as a convenience sample of students from the Department of Psychology and the Department of Music at Basel between September 2018 and June 2019. Exclusion criterion was age < 18 years.

Individuals with a lifetime diagnosis of OCD (n = 81) were recruited between September 2019 and January 2020 for another study by our group (Wahl et al., 2021) in clinics specializing in cognitive behavior therapy treatment of OCD. The majority of participants (n = 57; 70.37%) completed the relevant questionnaires (see “Measures”) at the beginning of the other study, before any experimental testing had started. The remaining participants took part in the current study some time after they had completed the other study (range 54–489 days ago, M = 257.54, SD = 110.39). They had all agreed to be contacted for future research. All met DSM-IV (American Psychiatric Association, 2000) criteria for OCD, as assessed with the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I; First et al., 1997; Wittchen et al., 1997), at the time of inclusion in the other study. Severity of OCD at the time of inclusion in the other study was assessed with the Yale–Brown Obsessive–Compulsive Scale (Y-BOCS; Goodman et al., 1989; Hand & Büttner-Westphal, 1991). The SCID-I and Y-BOCS were deliberately not repeated for the current study to reduce the time burden for individuals with OCD. For the same reason, individuals with OCD completed only a subset of the questionnaires used in individuals without OCD. Participants received course credit (psychology students only), gift vouchers, or monetary reimbursement for participation.

**Measures**

**Questionnaires to Assess Frequency, Interpretations, and Degree of Severity of IMI**

The Characteristics of Earworms Questionnaire (CEAR) was devised to investigate several aspects of recurrent IMI for which no standardized questionnaire exists. It

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1 For brevity, we refer to this group as individuals without OCD throughout the article.

2 For brevity, we refer to this group as individuals with OCD throughout the article.
starts with a definition of recurrent IMI and continues to assess general descriptors (e.g., frequency of IMI), interpretations, and other responses to IMI. Some items are modified versions of the Cognitive Intrusions Questionnaire (Freeston et al., 1991) and the Revised Obsessive Intrusions Inventory (ROII; Purdon & Clark, 1994). In this study, we used the CEAR to assess frequency and interpretations of recurrent IMI (please see the Online Supplement for the CEAR).

Frequency of recurrent IMI (CEAR Frequency) was assessed with the question, “How often does intrusive music enter your mind?” Answers were provided on a 9-point scale (1 = once a month or less, 3 = at least once a week, 5 = at least once a day, 7 = at least 5 times a day, and 9 = at least 20 times a day). Convergent validity of this measure (and others) was assessed by correlating measure scores with each other. These correlations are presented in Table 1. CEAR Frequency showed a high correlation with frequency ratings on the IMIS (Floridou et al., 2015), which can be considered an indicator of high convergent validity.

Dysfunctional interpretations of recurrent IMI (CEAR Interpretations) were assessed with six items on the CEAR. Three of these items were devised according to descriptions of dysfunctional interpretations of recurrent IMI in the literature (Rafin, 2016; Taylor et al., 2014), for example, “During the past week,

| Variable | Total sample \( (N=372) \) | Without OCD \( (n=291) \) | With OCD \( (n=81) \) |
|----------|-----------------------------|-----------------|----------------|
| Correlation of CEAR Frequency (predictor) with variable | | | |
| IMIS Frequency | — | 0.63 | — |
| CEAR Interpretations | 0.24 | 0.19 | 0.39 |
| Correlation of CEAR Interpretations (predictor) with variable | | | |
| OBQ Importance/Control of Thoughts | — | 0.37 | — |
| OBQ Perfectionism/Certainty | — | 0.20 | — |
| OBQ Responsibility/Threat Estimation | — | 0.13 | — |
| Correlation of SIMS (outcome) with variable | | | |
| CEAR Frequency | 0.34 | 0.30 | 0.42 |
| CEAR Interpretations | 0.39 | 0.28 | 0.69 |
| IMIS Negative Valence | — | 0.38 | — |
| IMIS Movement | — | 0.15 | — |
| IMIS Personal Reflections | — | 0.12 | — |
| IMIS Help | — | -0.03 | — |
| OCI-R | 0.14 | 0.16 | 0.21 |
| BDI-II | 0.11 | 0.25 | 0.03 |

BDI-II, Beck Depression Inventory-II; CEAR, Characteristics of Earworms Questionnaire; IMIS, Involuntary Musical Imagery Scale; OBQ, Obsessional Beliefs Questionnaire; OCD, obsessive–compulsive disorder; OCI-R, Obsessive–Compulsive Inventory-Revised; SIMS, Severity of Intrusive Musical Imagery Scale. The OCD sample did not complete the OBQ. Dashes indicate that data were not obtained.
to what extent did the sudden occurrence of the intrusive music make you think that you may not be able to stop thinking about it?” Three additional items were modifications of ROII (Purdon & Clark, 1994) items, for example, “During the past week to what extent did experiencing repetitive, intrusive music signal to you that you were going crazy?” Participants answered each item on a Likert-type scale (for details see the Online Supplement). To obtain a total score, the mean of the six items was calculated.

Positive correlations of CEAR Interpretations with the three OBQ subscales of small to medium size in individuals without OCD (Table 1) can be considered initial indicators of convergent validity. The internal consistency was good in individuals with and without OCD and the total sample (Table 2).

The severity of recurrent IMI, operationalized as the extent to which IMI meets criteria for obsessions defined by the DSM-5, was assessed with the self-developed Severity of Intrusive Musical Imagery Scale (SIMS): four items assessing the characteristics of obsessions defined by Criterion A1 in the DSM-5 (intrusive unwanted thoughts that occur repeatedly and persistently, causing marked anxiety or distress), one item assessing responses to the IMI according to Criterion A2 (attempts to ignore, suppress, or neutralize IMI), and one item each assessing the three impairing consequences of IMI defined in Criterion B (engagement with IMI lasts longer than 1 h/day; causes clinically significant distress; causes social, occupational, or other functional impairments; for a complete version of the SIMS, see the Online Supplement). Items were answered with yes or no. To obtain a total score, the sum across all items was calculated as an index of severity of recurrent IMI (main outcome). Correlations with the four subscales of the IMIS were taken as indicators of convergent and discriminant validity. As expected, the SIMS correlated positively with the Negative Valence subscale of the IMIS. The size of the association was small to medium and can be considered a preliminary indicator of convergent validity. Correlations with the remaining subscales of the IMIS were small or nonexistent, which can be considered a preliminary indicator of discriminant validity (for all correlations, see Table 1). Additionally, the SIMS showed a small positive association with severity of obsessions (OCI-R), which is consistent with the intended overlap in the constructs of the SIMS and obsessions. Finally, in individuals without OCD, the SIMS was also positively associated with severity of depressive symptoms. This indicates that the SIMS constructs conceptually overlap with depressive symptoms in individuals without OCD, but not in individuals with OCD. The internal consistency of the SIMS was acceptable in the total sample and in individuals without OCD and high in individuals with OCD (Table 2).

As an additional variable, we calculated if participants reported meeting criteria for musical obsessions as defined by Taylor et al. (2014). The dichotomous variable “DSM-5 criteria for obsessions” took the value 1 if participants answered yes to all questions referring to Criterion A1 (intrusive unwanted thoughts that occur repeatedly and persistently, causing marked anxiety or distress), Criterion A2 (attempts to ignore, suppress, or neutralize IMI), and Criterion B (engagement with IMI lasts longer than 1 h/day or causes clinically significant distress or causes social,
| Variable                                      | Total sample (N=372) | Without OCD (n=291) | With OCD (n=81) | \( \chi^2(1) \) | t (370)² | p    | d   |
|----------------------------------------------|----------------------|---------------------|-----------------|----------------|----------|-------|-----|
| Female⁵                                         | 286 76.88            | 234 80.41           | 52 64.20        | 9.75           | 0.003    |       |     |
| Years of education⁶                             |                      |                     |                 | 104.46         | <0.001    |       |     |
| 9–11                                          | 43 11.56             | 8 2.75              | 35 43.21        |               |          |       |     |
| 12–13                                         | 327 87.90            | 283 97.25           | 44 54.32        |               |          |       |     |
| Marital status                                |                      |                     |                 | 0.43           | 0.52     |       |     |
| With partner                                  | 140 37.63            | 107 36.77           | 33 40.74        |               |          |       |     |
| Without partner                               | 232 62.37            | 184 63.23           | 48 59.26        |               |          |       |     |
| DSM-5 criteria for obsessions                 | 7 1.88               | 3 1.03              | 4 4.94          | 5.24           | 0.04     |       |     |
| Psychopharmacological medication              |                      |                     |                 |               |          |       |     |
| Age (years)                                   | 26.02 8.91           | 24.03 6.10          | 33.16 12.93     | −6.17          | <0.001   | 0.90  |     |
| Severity of IMI (SIMS)                        | 1.92 1.85 0.75       | 1.95 1.76 0.72      | 1.80 2.14 0.83  | 0.59           | 0.56     | 0.08  |     |
| CEAR Interpretations                          | 1.90 1.20 0.80       | 1.95 1.19 0.79      | 1.72 1.25 0.85  | 1.52           | 0.13     | 0.19  |     |
| CEAR Frequency                                | 3.47 1.86            | 3.55 1.77           | 3.17 2.14       | 1.45           | 0.15     | 0.19  |     |
| BDI-I²                                        | 11.36 10.42 0.94     | 8.49 7.77 0.91      | 22.08 12.00 0.92| −9.48          | <0.001   | 1.34  |     |
| OCI-R²                                        | 17.04 11.88 0.89     | 14.96 11.04 0.90    | 24.78 11.77 0.82| −6.88          | <0.001   | 0.86  |     |
| OBQ Importance/Control of Thoughts            |                      |                     |                 | 2.27           | 1.11      | 0.89  |     |
| OBQ Perfectionism/Certainty                   |                      |                     |                 | 3.58           | 1.15      | 0.88  |     |
| OBQ Responsibility/Threat Estimation          |                      |                     |                 | 4.35           | 1.10      | 0.83  |     |
| IMIS Negative Valence⁷                         | 15.15 5.48 0.87      |                    |                 |               |          |       |     |
| IMIS Movement⁷                                 | 7.54 2.81 0.86       |                    |                 |               |          |       |     |
| IMIS Personal Reflections⁷                     | 4.70 1.88 0.70       |                    |                 |               |          |       |     |
Table 2 (continued)

| Variable                                | Total sample (N=372) | Without OCD (n=291) | With OCD (n=81) | $\chi^2(1)$ | t (370)$^a$ | p   | d   |
|-----------------------------------------|----------------------|---------------------|-----------------|-------------|-------------|-----|-----|
|                                         | n       | %       | M    | SD   | $\alpha$ | n       | %       | M    | SD   | $\alpha$ | n       | %       | M    | SD   | $\alpha$ |
| IMIS Help$^f$                           | 3.60    | 1.74    | 0.83 |      |           |           |         |       |      |      |           |           |         |       |      |      |
| Y-BOCS total                            |         |         |      |      |           |           | 19.29   | 6.80   | 0.86 |      |           |           |         |       |      |      |
| No. comorbid disorders                  |         |         |      |      |           |           |         |       |      |      |           |           |         |       |      |      |

$^a$Welch’s approximate $t$ values are reported with $df=90.12$ for age, $df=112.12$ for general frequency of IMI, and $df=94.99$ for BDI-II.

$^b$One individual without OCD reported “other” for gender. To meet the $\chi^2$ test assumptions, this participant was excluded from this analysis.

$^c$Two individuals with OCD had missing values.

$^d$Three individuals with OCD had missing values.

$^e$One individual without OCD and three individuals with OCD had missing values.

$^f$Three individuals without OCD had missing values.
occupational, or other functional impairments) on the SIMS and the value 0 if they answered no to any question.

**Standardized Questionnaires**

Obsessive–compulsive symptom severity was assessed with the Obsessive–Compulsive Inventory-Revised (OCI-R; Foa et al., 2002; Gönner et al., 2008) and depressive symptom severity with the Beck Depression Inventory-II (BDI-II; Beck et al., 1996; Hautzinger et al., 2006). Both are widely used measures with good validity and reliability. The OCI-R and BDI-II were used to provide preliminary indicators of convergent and discriminant validity of the SIMS.

The Involuntary Musical Imagery Scale (IMIS; Floridou et al., 2015) assesses involuntary musical imagery with four subscales. The Negative Valence subscale assesses negative consequences of IMI such as intensive efforts to stop IMI (e.g., “I try to block it”), emotional consequences such as worry or irritation, and general negative evaluations of IMI (e.g., “The experience of my earworms is unpleasant”). The Movement subscale assesses body movement that matches IMI rhythms. The Personal Reflections subscale assesses the interpretation of IMI as being related to unresolved personal issues or concerns, and the Help subscale assesses the perceived usefulness of IMI (Floridou et al., 2015). The IMIS has shown good reliability and validity (Cotter & Silvia, 2017; Floridou et al., 2015). In our study, the IMIS was used to provide preliminary indicators of convergent and discriminant validity of the SIMS and CEAR Frequency.

The Obsessive–Compulsive Beliefs Questionnaire (OBQ; Ertle et al., 2008) assesses three dysfunctional belief domains relevant to the development and maintenance of OCD: (a) importance and control of thoughts, (b) perfectionism and intolerance of uncertainty, and (c) inflated responsibility and overestimation of threat. It was included to provide an indication of the validity of CEAR Interpretations. The OBQ has high reliability and adequate validity (Ertle et al., 2008). It was explicitly conceptualized as a dimensional measure (Obsessive Compulsive Cognitions Working Group, 1997) and therefore is also applicable to individuals who have not been diagnosed with OCD. In the current study, the internal consistencies of all standardized measures were high to excellent with the exception of the IMIS Personal Reflections subscale, which showed acceptable consistency (Table 2). All measures were provided in German.

**Procedure**

All participants provided written informed consent prior to participation. The study aim was described as investigating the associations between musical involvement, personal characteristics, and stress. Participants completed the questionnaires online via LimeSurvey (LimeSurvey Project, 2012). The first questionnaire collected demographic data (age, gender, years of education, and marital status) and was
followed by questionnaires for individuals without OCD in the following order: the CEAR, the OBQ, the IMIS, the BDI-II, the SIMS, and the OCI-R. Individuals with OCD completed the CEAR, the BDI-II, the SIMS, and the OCI-R. The study was approved by the ethics committee of the Faculty of Psychology, University of Basel, 026–18–1, and by the ethics committee of North-West Switzerland, 2017–01,980.

**Statistical Analysis and Models**

**Participant Characteristics**

Potential differences between the two samples in terms of sociodemographic data and the frequency (CEAR Frequency), interpretation (CEAR Interpretations), and severity (SIMS) of IMI were investigated using chi-square tests for the dichotomous variables (gender, years of education, marital status, musical obsessions [i.e., self-reported DSM-5 criteria]) and t tests for independent samples for the remaining variables (age, CEAR Frequency, CEAR Interpretations, SIMS, depressive symptoms, obsessive–compulsive symptoms).

**Zero-Order Associations Between Predictors and Outcome**

Zero-order associations between the predictors (CEAR Frequency and CEAR Interpretations) and outcome (SIMS) were analyzed using Pearson product-moment correlations. Effect sizes were interpreted according to Cohen (1988).

**Testing the Interaction Effect of Frequency and Interpretations on Severity of IMI**

A quasi-Poisson model was used to analyze the data. Poisson models are typically used when the outcome is a count variable (such as the SIMS in our study) and when the distribution is skewed right, especially if the expected value of its parameter ($\lambda$) is small. Note that the distribution of the SIMS was indeed skewed right (Fig. 1). Since count data often exhibit greater variance than expected from a

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**Fig. 1** The frequency distribution of the outcome variable severity of intrusive musical imagery. **A** Individuals without OCD. **B** Individuals with OCD. IMI, Intrusive Musical Imagery; SIMS, Severity of Intrusive Musical Imagery Scale.
Poisson distribution, the resulting overdispersion must be accounted for. Since our data were overdispersed, we used a quasi-Poisson model, in which standard errors are increased according to the amount of overdispersion relative to the ordinary Poisson model. The predictors were transformed since their frequency distributions were both skewed (log transformation for CEAR Interpretations and square root transformation for CEAR Frequency) to avoid undue influence of outliers on our model, using Cook’s distance as measure of influence (Fox, 2016).

We specified a model with severity of recurrent IMI (SIMS) as outcome, and frequency (CEAR Frequency) and dysfunctional interpretations (CEAR Interpretations) as predictors, including their interaction. Thus, we tested whether recurrent IMI was particularly high if both frequency and interpretation were elevated. Since the sample (with or without OCD) might conceivably have an influence on the results, the sample membership (OCD vs controls) was controlled for in the model. We have focused on the overall interaction in this initial testing of the two-factor model and depict the suggested moderations graphically, since the two-factor model of musical obsessions (Taylor et al., 2014) does not state explicitly which is the moderating variable. Significance level $\alpha$ was set to 5%.

## Results

### Participant Characteristics and Frequency of Self-reported DSM-5 Criteria for Musical Obsessions

Table 2 shows participant characteristics, test statistics, and effect sizes for group differences between individuals with and without OCD. The sample without OCD included a higher percentage of women than the sample with OCD and reported a higher level of education. On average, individuals with OCD were older than individuals without OCD and, unsurprisingly, had more severe depressive and obsessive–compulsive symptoms. These group differences were large. Taking the OCI-R total scores as benchmarks for level of severity of OCD (Abramovitch et al., 2020), individuals without OCD demonstrated, on average, mild symptom severity, and individuals with OCD, moderate-severe symptom severity. Individuals with and without OCD did not differ in the average frequency of IMI, interpretations, or severity of IMI. The mean values on the OBQ and IMIS subscales in individuals without OCD were comparable to previous non-OCD samples (e.g., Cotter & Silvia, 2017; Wahl, Hofer, et al., 2020; Wahl, Lieb, et al., 2020). Individuals with OCD were characterized by a moderate severity of OCD and had, on average, 1.5 comorbid mental disorders; 73% were taking psychopharmacological medication.

Less than 2% of all participants reported meeting all A and B criteria of the DSM-5 for musical obsessions. This percentage was higher in individuals with OCD compared to individuals without OCD (see Table 2).
Zero-Order Associations Between Predictors and Outcome

Table 1 shows the intercorrelations of predictors and outcome. CEAR Frequency and CEAR Interpretations (predictors) were correlated to a small to medium degree in the total sample and in individuals with and without OCD. CEAR Frequency was correlated with the SIMS (outcome) to a small to medium degree in the total sample and in individuals with and without OCD. CEAR Interpretations were correlated with the SIMS to a small to medium degree in the total sample and in individuals without OCD, and to a large degree in individuals with OCD.

Testing the Interaction Effect of Frequency and Interpretations on Severity of IMI

Results for the quasi-Poisson models are presented in Table 3. We found evidence for an interaction effect between CEAR Frequency and CEAR Interpretations when predicting the SIMS. When one multivariate outlier (Cook’s distance = 0.24) was removed, the overall pattern of results did not change (Table 3), and the interaction effect became even stronger. The interaction can be interpreted in two ways. First, the strength of the positive association between CEAR Interpretations and the SIMS depends on CEAR Frequency (Fig. 2). In particular, the positive association between CEAR Interpretations and the SIMS was stronger for low frequencies than for moderate or high frequencies. Second, the association between the SIMS and CEAR Frequency depends on the degree of agreement with CEAR Interpretations. In particular, the positive association between CEAR Frequency and the SIMS was stronger for a low degree of agreement with CEAR Interpretations than for moderate or high agreements.

Table 3 Quasi-Poisson models predicting severity of IMI (SIMS)

| Predictor                                      | IRR [95% CI] | t   | df  | p   |
|------------------------------------------------|--------------|-----|-----|-----|
| Model for all participants (N=372)            |              |     |     |     |
| Sample                                         | 1.07 [0.87, 1.32] | 0.62 | 367 | 0.54 |
| CEAR Frequency                                 | 2.24 [1.70, 2.94] | 5.79 | 367 | <0.001 |
| CEAR Interpretations                           | 4.10 [2.25, 7.48] | 4.61 | 367 | <0.001 |
| CEAR Frequency × CEAR Interpretations          | 0.66 [0.49, 0.90] | −2.65 | 367 | 0.01 |
| Model excluding one multivariate outlier (N=371) |              |     |     |     |
| Sample                                         | 1.07 [0.87, 1.32] | 0.67 | 366 | 0.50 |
| CEAR Frequency                                 | 2.35 [1.78, 3.11] | 6.05 | 366 | <0.001 |
| CEAR Interpretations                           | 5.46 [2.87, 10.42] | 5.16 | 366 | <0.001 |
| CEAR Frequency × CEAR Interpretations          | 0.58 [0.42, 0.81] | −3.27 | 366 | 0.001 |

CEAR, Characteristics of Earworms Questionnaire; CI, confidence interval; IMI, intrusive musical imagery; IRR, incidence rate ratio; SIMS, Severity of Intrusive Musical Imagery Scale.
Discussion

The study’s aim was to test the predictions of the two-factor model of musical obsessions (Taylor et al., 2014). We indeed found an interaction effect between frequency and dysfunctional interpretations of recurrent IMI when predicting severity of IMI. However, unlike suggested in our hypothesis, the severity of recurrent IMI was not particularly high if dysfunctional interpretation and frequency of IMI were both elevated. Instead, we found that the less frequent the IMI, the stronger the positive relationship between dysfunctional interpretations and severity of IMI, or, put another way, the lower the agreement with the dysfunctional interpretations, the stronger the positive relationship between frequency and severity of recurrent IMI.

Thus, although the interaction is consistent with the two-factor model’s overall idea that frequency and appraisals of recurrent IMI are involved in the development and maintenance of musical obsessions, our results point to an interaction effect in which even infrequent IMI may lead to elevated severity of recurrent IMI, provided that these are interpreted in a dysfunctional way (i.e., high values of dysfunctional interpretations). This is inconsistent with the two-factor model’s statement that “if a person rarely or never experiences normal IMI, then the opportunity to misinterpret the meaning or significance of the intrusions does not arise” (Taylor et al., 2014, p. 585). One might speculate about why the relationship between dysfunctional interpretations and
severity of recurrent IMI is particularly high when the frequency of IMI is low. One possibility is that infrequent IMI might occur unexpectedly and out of context (Audet et al., 2020), and thus might be particularly prone to interpretation as personally relevant. Recurrent IMI with moderate frequency, in comparison, might result in quicker habituation and thus might not be particularly prone to further attention and information processing, such as dysfunctional interpretations. Future studies will have to clarify this inconsistency between our findings and the model by focusing particularly on the role of infrequent IMI and their potential for dysfunctional interpretations.

It is important to note that our cross-sectional study precludes any temporal or causal conclusions. For example, the results are also consistent with the assumption that the more severe the recurrent IMI, the more dysfunctional it is interpreted to be, in particular if it occurs infrequently. Future experimental or longitudinal studies need to include temporal and causal relations to draw firm conclusions about the validity of the two-factor model.

Recurrent IMI that is likely to meet criteria for obsessions according to the DSM-5 was rare in individuals with OCD (5%) and very rare in individuals without OCD (1%). Comparable percentages from other studies are lacking. Previous studies including individuals without a known diagnosis of OCD found that 25–35% of recurrent IMI is perceived as distressing (Beaman & Williams, 2010; Liikkanen, 2012), and that the average distress associated with recurrent IMI is low (Reuman et al., 2020). Thus, our results are consistent with the idea that distressing recurrent IMI is an infrequent experience. Our data suggest that individuals with OCD are more prone to musical obsessions than individuals without OCD, and this finding is consistent with positive correlations between the disturbance caused by recurrent IMI and obsessive–compulsive symptoms (Floridou et al., 2015; Muellensiefen et al., 2014; Williamson & Müllensiefen, 2012).

Several limitations of the study should be considered. First, we did not use standardized measures to assess the main variables because no such measures exist. To provide preliminary information about the validity of our measures, we report associations with standardized measures of similar constructs. Second, we considered only the first expression of individual differences in recurrent IMI (frequency) and not the second (persistence) suggested by Taylor et al. (2014). For this initial test of the model, we focused on retrospective frequency ratings that were likely to be assessed in a relatively valid and reliable way (Wahl, Lieb et al., 2020). Third, the current diagnostic and medication status of individuals with OCD was unknown since assessments took place some time prior to inclusion in the study. What we can safely say is that participants had a lifetime diagnosis of OCD and were familiar with experiencing obsessions and/or compulsions. Fourth, our measure of severity of recurrent IMI (the SIMS) showed some overlap with depressive symptoms in individuals without OCD but not in individuals with OCD and we cannot exclude the possibility that it assessed slightly different aspects of severity of recurrent IMI in the two samples. Finally, our estimation of the frequency of musical obsessions relied entirely on self-report and future studies should assess musical obsessions using standardized clinician ratings such as the SCID and Y-BOCS.

To conclude, the predictions of the two-factor model of musical obsessions were not fully supported in this initial investigation. Our findings suggest that infrequent IMI might be also interpreted in a dysfunctional way. This question is relevant to
future modifications of the two-factor model and also for case conceptualizations in the treatment of musical obsessions. When future studies, including longitudinal and experimental studies, investigate the predictions of the two-factor model, they need to take into account our initial findings and pay particular attention to low-frequency IMI. Future studies should also investigate whether the discussed relationships between severity of recurrent IMI, frequency, and dysfunctional interpretations equally apply to both the development and maintenance of musical obsessions.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s41811-022-00136-y.

**Author Contribution** KW conceptualized and designed the study. Data analysis was performed by KW and CVH under supervision of AHM. The first draft of the manuscript was written by KW and RL provided critical feedback. All authors read and approved the final manuscript.

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**Data Availability** The data sets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics Approval** All procedures involving human participants were conducted in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the ethics committee of the Faculty of Psychology, Basel, 026–18–1, and by the ethics committee of North-West Switzerland, 2017–01980.

**Consent to Participate/Consent for Publication** Informed consent was obtained from all individual participants included in the study and additionally, patients signed informed consent regarding publishing their data.

**Conflict of Interest** The authors declare no competing interests.

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