Trait phenomenological control predicts visually evoked auditory response.

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Abstract

Up to 40% of people report visually evoked auditory responses (vEARs; for example, ‘hearing’ sounds in response to watching silent videos). We investigate the degree to which vEAR experiences may arise from phenomenological control, i.e. from the way people can control their experience to meet expectancies arising from imaginative suggestion. In the experimental situation, expectancies arise from demand characteristics (cues which communicate beliefs about experimental aims to participants). Trait phenomenological control has been shown to substantially predict experimental measures of changes in ‘embodiment’ experience in which demand characteristics are not controlled (e.g., mirror touch and pain, and experiences of ownership of a fake hand). Here we report substantial relationship between scores on the Phenomenological Control Scale (PCS; a test of direct imaginative suggestion) and vEAR scores (reports of auditory experience for silent videos) which indicate that vEAR experience may be an implicit imaginative suggestion effect. This study demonstrates that relationships of trait phenomenological control with subjective reports about experience are not limited to embodiment and may confound a wide range of measures in psychological science.

Trait phenomenological control predicts visually evoked auditory response.

Some people report experience of auditory sensations in response to moving visual stimuli (Saenz & Koch, 2008), for example, hearing sound when watching silent video. Such visually evoked auditory responses (vEARs) are common: large scale studies show prevalence of between 20% and 40% percent (Fassnidge & Freeman, 2018; Freeman, 2020). Because of its cross-modal nature, vEAR has been conceptualised as a form of synaesthesia (Fassnidge et al., 2017; alternatively 'hearing-motion' synaesthesia, Rothen et al., 2017), and inter-individual variation in vEAR has been attributed to mechanisms which have been proposed to underlie synaesthesia: for example, individual differences in inhibition of information between cortical areas associated with visual and auditory processes (Fassnidge et al., 2019). Notably, vEAR is not restricted to the laboratory; an online forum for exchanging silent videos which are anticipated to lead to auditory sensation has 315,000 members (<https://www.reddit.com/r/noisygifs/>; 16/05/2021).

Response to expectancies arising from demand characteristics presents a different potential explanation for vEAR. Demand characteristics are any aspects of the experimental situation (including participant's prior beliefs) which can influence expectancies for the experimental procedure (Orne, 1962; Sharpe & Whelton, 2016), e.g., through hypothesis awareness (see Corneille & Lush, 2021). Historically, hypothesis awareness has primarily been thought to drive faking, but it may also lead to changes in *experience* in psychology experiments by the same mechanisms operative in response to direct imaginative suggestion (Kirsch & Council, 1989; Lush et al., 2020; Michael et al., 2012). There are substantial relationships between trait response to direct imaginative suggestion (which we term *phenomenological control*; Dienes, Lush, et al., 2020; Lush, Scott, et al., 2021) and reports of experimentally induced 'embodiment' experiences (mirror touch, mirror pain and rubber

hand effects; Lush et al., 2020). We argue that these relationships indicate that measures of these effects are attributable (partially or entirely) to phenomenological control, rather than, or in addition to, other proposed mechanisms. Here we test predictions of the theory that phenomenological control mechanisms drive vEAR experience.

The ability to respond to imaginative suggestion (measured with imaginative suggestion scales) is a stable trait which has been primarily studied within the context of hypnosis. However, response to imaginative suggestion does not require the hypnotic context (Barber, 1965; Hull, 1933; see Lynn et al., 2020 for a review of myths about hypnosis). We refer to the ability to meet expectancies by generating experience as phenomenological control to avoid inaccurate connotations of the term ‘hypnosis’ (e.g., that response requires a special ‘state’) and also confusion with other definitions of “suggestibility” (e.g., social compliance), which are not necessarily operative in response to imaginative suggestion. The Phenomenological Control Scale (PCS; Lush, Scott, et al., 2021) is an adaptation of the Sussex Waterloo Scale of Hypnotisability (SWASH; Lush et al., 2018) with all reference to hypnosis removed. It consists of ten imaginative suggestions for a range of experiences (including auditory and gustatory hallucination, amnesia and paralysis) which participants report on a 0-5 scale (for another recent non-hypnotic scale of response to imaginative suggestion see Oakley et al., 2021)

Here we replicate reports of auditory response to silent videos (Freeman; 2020) and measure trait response to direct imaginative suggestion (with the PCS; Lush, Scott, et al., 2021) in a large sample. If auditory experience in response to silent visual stimuli arises (at least partially) from phenomenological control in response to expectancies, vEAR and PCS scores should be related.

92 **Method**

93 **Participants**

94 The study was conducted as an online practical for a University of Sussex 1st year
 95 undergraduate course. A total of 452 participants (354 female, 92 male, 5 other, 1 did not say)
 96 successfully completed the full online study providing both PC and vEAR scores (mean age
 97 = 19.4, SD = 2.7). Ethical approval was received from the University of Sussex Sciences &
 98 Technology Cross-Schools Research Ethics Committee (ER/RBS20/11) and informed
 99 consent was obtained.

100 **Procedure**

101 The Gorilla Experiment Builder (www.gorilla.sc) was used to create and host the
 102 experiment (Anwyl-Irvine et al., 2020). Participants completed the study remotely between
 103 the 19th of October 2020 and the 14th of December 2020. All instruction was provided by
 104 computer; onscreen or over headphones.

105 Participants were first presented with information about the study and asked to
 106 consent to participate. They were then given the opportunity to provide contact details for
 107 inclusion in a participant recruitment database, and asked to provide basic demographic
 108 information (age and gender). At this point participants were instructed to put on their
 109 headphones before continuing. The computer based PCS screening (see Palfi et al., 2018)
 110 then commenced following the procedure reported in (Lush, Scott, et al., 2021). The PCS
 111 procedure began with a recorded preamble which describes the session as a test of the use of
 112 imagination to create experience. Ten imaginative suggestions were then delivered in fixed
 113 order (see Lush, Scott, et al., 2021).

114 After the imaginative suggestions, participants reported subjective scale PCS (Lush et
 115 al, 2021). This scale records experience (for example how much it felt like there was a

magnetic force drawing the hands together) on a Likert scale (from 0-5). Anchor points were provided for each scale item individually. Responses were recorded by participants pressing number keys on the computer keyboard. See the materials at <https://osf.io/4x25a/> for scripts, audio, slides, response texts and scoring procedures.

The vEAR evaluation directly followed the PCS screening. The procedure and materials were taken from Freeman (2020; materials available at <https://osf.io/4wyde/>). Participants were first presented with text describing the study as an investigation of imaginary sounds evoked by visual motion, and informing participants to interpret a range of experiences as auditory sensations. The text also informed participants that auditory sensations should occur with ‘visual change over time’ and with ‘motion or sudden flashes’.

After reading the introductory text participants completed a questionnaire about a range of experiences in their daily lives (e.g., phosphenes, synaesthesia, tinnitus; from Freeman (2020)) and then were presented with another introductory text, before being shown the videos. This second introductory text informed them to rate how intense their auditory experience was, instructed them to listen carefully, and defined the anchor points for the scale as zero (no auditory sensation at all) and five (very vivid and definite auditory sensation). Sixteen silent videos of abstract motion (see Freeman, 2020) were then presented in random order. Scale ratings were displayed beneath each video with participants required to select a given rating number and then click a separate ‘Submit Rating’ button to move on to the next video. Videos looped until submit rating was selected.

After the vEAR evaluation participants completed the Penn State Worry Questionnaire (PSWQ) (for purposes unrelated to this study) and were thanked for their participation.

Measures

PCS score was calculated from mean response to the ten PCS items (0-5 scale). vEAR response was the mean response to the 16 videos of abstract moving images (0-5 scale). Questionnaire responses were also recorded (see supplementary measures).

Analyses

All data are available at <https://osf.io/a2skp/>. No pre-registration of analyses was conducted for this study and the presented analyses are therefore exploratory. A Bayes factor for the raw slope of vEAR score regressed onto PCS score was modelled by considering what the maximum slope could be, given the vEAR mean and the PCS mean. A plausible maximum slope would obtain if people scoring 0 (no subjective response) on the PCS scale also scored 0 (no subjective response) on the vEAR scale; i.e. a plausible maximum slope can be estimated as the line from (mean vEAR, mean PCS) to (0, 0) (this is the ratio-of-mean heuristic described in Dienes, 2019). The maximum slope was thus estimated as .54 vEAR Likert units per PCS Likert unit. H1 was therefore modelled using a half-normal with an SD equal to .27 vEAR Likert units per PCS Likert units, half the maximum slope of 0.54.

Bayes factors were calculated with the calculator at: <https://harry-tattan-birch.shinyapps.io/bayes-factor-calculator/>. Robustness Regions (RR), were determined as the set of scale factors that led to the same qualitative conclusion, i.e. either $B > 3$, or $B < 1/3$; or $1/3 < B < 3$ (Dienes, 2019).

See supplemental material for questionnaire descriptive statistics and correlational analyses of pre-vEAR questionnaire responses with PCS and vEAR report.

Results

Mean PCS score (mean response on a 0-5 scale to ten imaginative suggestions) was 1.8 (SD = 0.7). Mean vEAR score (mean response on a 0-5 scale to videos) was 1.0 (SD = 0.9).

PCS score predicted vEAR score (figure 1), $b = .48$ vEAR Likert units / PCS Likert unit (SE = 0.06), $t(450) = 8.50$, $p < 0.001$, 95% CI [.37, .60], $R^2 = 0.14$, $B_{H(0,.27)} = 7.61 \times 10^{12}$, $RR = [< .01, >6]$.

Figure 1. Mean vEAR score on PCS score, Spearman's $r_s = .38$, 95% CI [.29, .45]. Error bars show 95% CI. The centre of credibility intervals is the predicted score.

Discussion

Phenomenological Control Scale scores predicted visually evoked auditory response scores by approximately half a point for each PCS scale point increase. The correlation between vEAR response and PCS is similar to item-total correlations for PCS items (Lush, Scott, et al., 2021). This substantial relationship suggests that reported experiences of auditory sensation in response to visual stimuli may arise from phenomenological control effects rather than or in addition to other mechanisms.

The notion that vEAR experiences may be attributable to uncontrolled demand characteristics is compatible with vEAR occurring outside of the experimental situation, and with the relevant demand characteristics arising also outside the experimental procedure. Phenomenological control may be employed in a wide range of contexts, (see Dienes, Lush, et al., 2020; Lush et al., 2020). Note also that people (whether in an experimental context or not) may remain entirely unaware they are responding to expectancies. Response to imaginative suggestion (phenomenological control) may involve strategic changes in metacognitive processes, so that an intentional act is experienced as unintentional (cold control theory; Dienes, 2012). Everyday experiences of auditory sensation in response to purely visual imagery (or an experience of pain or touch in response to seen touch or apparently painful stimuli) may be habitual but intentional acts of imagination, which are experienced as *unintentional* (Dienes, Lush, et al., 2020; Dienes, Palfi, et al., 2020).

Following Freeman (2020) we also recorded responses to a questionnaire about a range of experiences in everyday life. Because these questionnaire responses were taken after introductory information about vEAR was provided (as in Freeman, 2020), the results are likely to be confounded by demand characteristics and are therefore not interpreted (reverse scoring of questionnaire responses does not take into account expectancies). For statements

for which no obvious demand characteristics relate to vEAR, the correlation with PC was small in magnitude (e.g., for insomnia, 95% CI[-.09, +.09]; see supplemental material).

While we focus here on subjective report, indirect or ‘objective’ measures are not necessarily resistant to demand characteristics (see Lush, Seth, et al., 2021 for investigation of expectancies in indirect measures of rubber hand effects). Speed of stimuli (or ‘motion energy’) has been proposed as an objective measure of vEAR experience (Freeman, 2020). However, participants may simply expect stronger effects for faster stimuli.

A limitation of this study is that, because both scales were measured in the same study, the PCS scale may have influenced expectancies for the vEAR scale. While similar relationships have been reported for other effects (mirror touch and mirror pain) when data was collected in entirely separate contexts, future studies wishing to gain a clearer picture of the extent of PC influence on vEAR should collect data in (from participant’s perspectives) apparently unrelated studies.

This is the fourth recent example (from our group) of psychological effects which are substantially predicted by phenomenological control. The previously reported effects (Lush et al., 2020) are all related in some way to embodiment experience, raising the potential concern that phenomenological control may be significant only for body-related experiences. The present study alleviates this concern. Note also that the reported relationship between vEAR and PCS scores is not dependent on response to imaginative suggestions for auditory experience; the relationship between the mean of 8 PCS items which do not require auditory experience and vEAR scores remains substantial (see supplemental material).

To control for phenomenological control effects, an experimental condition in which effects are predicted by a specific theory can be controlled by a condition which is closely matched to the experimental condition in two aspects: (i) expectancies and (ii) difficulty of

responding to those expectancies with phenomenological control. Controls matched for expectancies can be developed using expectancy studies (Orne's 'quasi -experiments'; Orne, 1962; see Lush, 2020; Lush, Seth, et al., 2021 for recent examples). The second aspect - difficulty of responding by phenomenological control - can be addressed by comparing responses to direct imaginative suggestions for control and experimental effects. Comparison of experimental measures with control measures which have been closely matched in both expectancies and demand characteristics will minimize the confounding influence of phenomenological control (see Lush, 2020).

As we have previously argued (Dienes, Lush, et al., 2020; Dienes, Palfi, et al., 2020; Lush et al., 2020), we anticipate that phenomenological control may confound a wide range of experimental measures. It is not safe to assume that a given effect is not attributable to demand characteristics just because participants (or even experimenters) report striking changes in experience, because there are accompanying physiological changes, or because participants report experiencing the effect in everyday life. Studies which aim to establish evidence for mechanisms underlying changes in experience require the control of demand characteristics and of trait differences in phenomenological control.

Finally, observations of substantial relationships between perceptual experiences and trait phenomenological control present new opportunities as well as challenges for psychological research. Further investigation of phenomenological control holds promise not only for guarding against unanticipated confounds in psychological experiments, but also for revealing the cognitive and neural underpinnings of perceptual experience in general.

References

- Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, 52(1), 388–407. <https://doi.org/10.3758/s13428-019-01237-x>
- Barber, T. X. (1965). Measuring “Hypnotic-Like” Suggestibility with and without “Hypnotic Induction”; Psychometric Properties, Norms, and Variables Influencing Response to the Barber Suggestibility Scale (BSS). *Psychological Reports*, 16(3), 809–844. <https://doi.org/10.2466/pr0.1965.16.3.809>
- Corneille, O., & Lush, P. (2021). *Sixty years after Orne’s American Psychologist article: A conceptual analysis of “Demand Characteristics”*. PsyArXiv. <https://doi.org/10.31234/osf.io/jqyvx>
- Dienes, Z. (2012). Is hypnotic responding the strategic relinquishment of metacognition? In *Foundations of metacognition* (pp. 267–278). Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780199646739.003.0017>
- Dienes, Z., Lush, P., Palfi, B., Roseboom, W., Scott, R., Parris, B., Seth, A., & Lovell, M. (2020). Phenomenological control as cold control. *Psychology of Consciousness: Theory, Research, and Practice*, No Pagination Specified-No Pagination Specified. <https://doi.org/10.1037/cns0000230>
- Dienes, Z., Palfi, B., & Lush, P. (2020). *Controlling phenomenology by being unaware of intentions*. PsyArXiv. <https://doi.org/10.31234/osf.io/4zw6g>
- Fassnidge, C., Ball, D., Kazaz, Z., Knudsen, S., Spicer, A., Tipple, A., & Freeman, E. (2019). Hearing through Your Eyes: Neural Basis of Audiovisual Cross-activation, Revealed by Transcranial Alternating Current Stimulation. *Journal of Cognitive Neuroscience*, 31, 1–14. https://doi.org/10.1162/jocn_a_01395

- 268 Fassnidge, C., Cecconi Marcotti, C., & Freeman, E. (2017). A deafening flash! Visual
 269 interference of auditory signal detection. *Consciousness and Cognition*, 49, 15–24.
 270 <https://doi.org/10.1016/j.concog.2016.12.009>
- 271 Fassnidge, C. J., & Freeman, E. D. (2018). Sounds from seeing silent motion: Who hears
 272 them, and what looks loudest? *Cortex*, 103, 130–141.
 273 <https://doi.org/10.1016/j.cortex.2018.02.019>
- 274 Freeman, E. D. (2020). Hearing what you see: Distinct excitatory and disinhibitory
 275 mechanisms contribute to visually-evoked auditory sensations. *Cortex*, 131, 66–78.
 276 <https://doi.org/10.1016/j.cortex.2020.06.014>
- 277 Hull, C. L. (1933). *Hypnosis and suggestibility* (pp. xii, 416). Appleton-Century.
- 278 Kirsch, I., & Council, J. R. (1989). Response expectancy as a determinant of hypnotic
 279 behavior. In *Hypnosis: The cognitive-behavioral perspective* (pp. 360–379).
 280 Prometheus Books.
- 281 Lush, P. (2020). Demand Characteristics Confound the Rubber Hand Illusion. *Collabra:*
 282 *Psychology*, 6(1), 22. <https://doi.org/10.1525/collabra.325>
- 283 Lush, P., Botan, V., Scott, R. B., Seth, A. K., Ward, J., & Dienes, Z. (2020). Trait
 284 phenomenological control predicts experience of mirror synaesthesia and the rubber
 285 hand illusion. *Nature Communications*, 11(1), 4853. [https://doi.org/10.1038/s41467-](https://doi.org/10.1038/s41467-020-18591-6)
 286 [020-18591-6](https://doi.org/10.1038/s41467-020-18591-6)
- 287 Lush, P., Moga, G., McLatchie, N., & Dienes, Z. (2018). The Sussex-Waterloo Scale of
 288 Hypnotizability (SWASH): Measuring capacity for altering conscious experience.
 289 *Neuroscience of Consciousness*, 2018(1). <https://doi.org/10.1093/nc/niy006>
- 290 Lush, P., Scott, R. B., Seth, A., & Dienes, Z. (2021). *The Phenomenological Control Scale:*
 291 *Measuring the capacity for creating illusory nonvolition, hallucination and delusion.*
 292 PsyArXiv. <https://doi.org/10.31234/osf.io/zhgeb>

- 293 Lush, P., Seth, A., & Dienes, Z. (2021). *Demand characteristics confound asynchronous*
294 *control conditions in indirect measures of the rubber hand illusion*. PsyArXiv.
295 <https://doi.org/10.31234/osf.io/w67xc>
- 296 Michael, R. B., Garry, M., & Kirsch, I. (2012). Suggestion, Cognition, and Behavior. *Current*
297 *Directions in Psychological Science*, 21(3), 151–156.
298 <https://doi.org/10.1177/0963721412446369>
- 299 Oakley, D. A., Walsh, E., Mehta, M. A., Halligan, P. W., & Deeley, Q. (2021). Direct verbal
300 suggestibility: Measurement and significance. *Consciousness and Cognition*, 89,
301 103036. <https://doi.org/10.1016/j.concog.2020.103036>
- 302 Orne, M. T. (1962). On the social psychology of the psychological experiment: With
303 particular reference to demand characteristics and their implications. *American*
304 *Psychologist*, 17(11), 776–783. <http://dx.doi.org/10.1037/h0043424>
- 305 Palfi, B., Lush, P., Scott, R. B., & Dienes, Z. (2018). *Can hypnotic suggestibility be*
306 *measured online?* [Preprint]. PsyArXiv. <https://doi.org/10.31234/osf.io/xz9by>
- 307 Rothen, N., Bartl, G., Franklin, A., & Ward, J. (2017). Electrophysiological correlates and
308 psychoacoustic characteristics of hearing-motion synaesthesia. *Neuropsychologia*,
309 106, 280–288. <https://doi.org/10.1016/j.neuropsychologia.2017.08.031>
- 310 Saenz, M., & Koch, C. (2008). The sound of change: Visually-induced auditory synesthesia.
311 *Current Biology*, 18(15), R650–R651. <https://doi.org/10.1016/j.cub.2008.06.014>
- 312 Sharpe, D., & Whelton, W. J. (2016). Frightened by an Old Scarecrow: The Remarkable
313 Resilience of Demand Characteristics. *Review of General Psychology*, 20(4), 349–
314 368. <https://doi.org/10.1037/gpr0000087>

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322 **Author contributions**

323 PL, Z.D. and R.B.S designed the study. R.B.S programmed the Gorilla.sc study and collected
324 data and P.L performed analyses and drafted the manuscript. All authors provided critical
325 revisions