

Mitigating Motion Sickness by Anticipatory Cues

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Supplementary Information

Motion stimulus

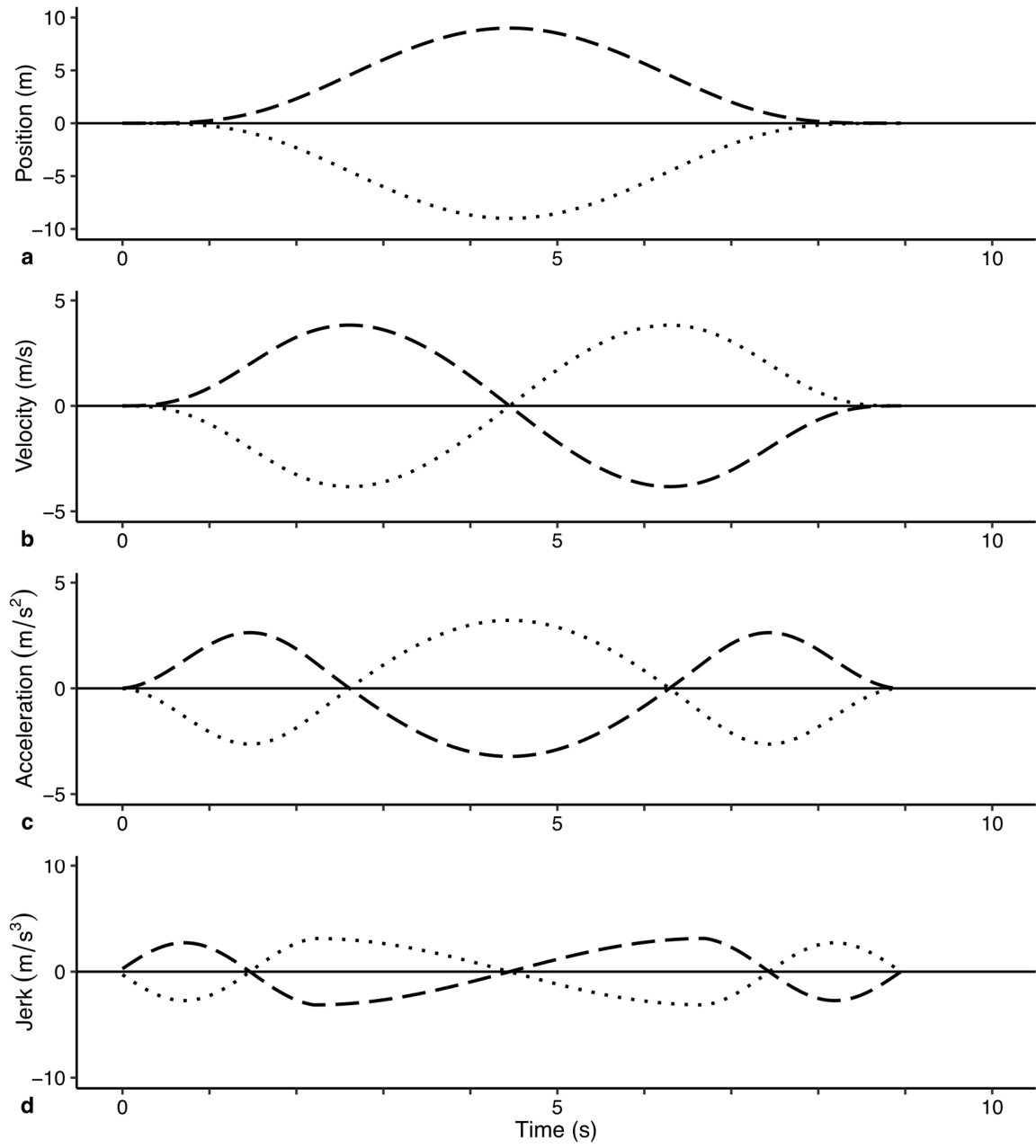


Figure S1. The parameters for one motion starting in the forward direction (dashed lines) and one motion starting in the backward direction (dotted lines).

Converting R to a measure of percentage change

To provide the reader guidance on the interpretation of our measure, we provide a conversion of R to a percentual change in MISC scores (i.e., $S = (1 - A/C) \times 100$) in the figure below. Note that we use the measure R instead of a percentage change because for R_{ti} , exchanging C and A only results in a change of sign. This makes it suitable for averaging: if C and A are drawn from a random distribution, the average of R will be zero, whereas the average of S will become negative.

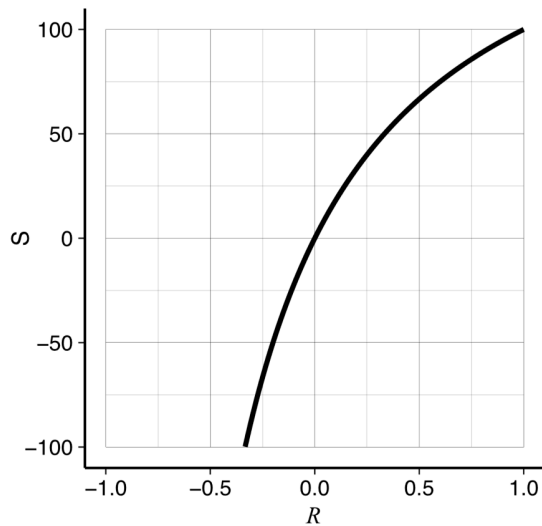


Figure S2. Guidance to the interpretation of our measure R expressed in terms of a percentual change in MISC scores from the anticipatory to the control session ($S = (1 - A/C) \times 100$). Note that because S is an asymmetrical measure, R values lower than -0.4 correspond to extremely large negative values of S .

Development of MISC scores per participant

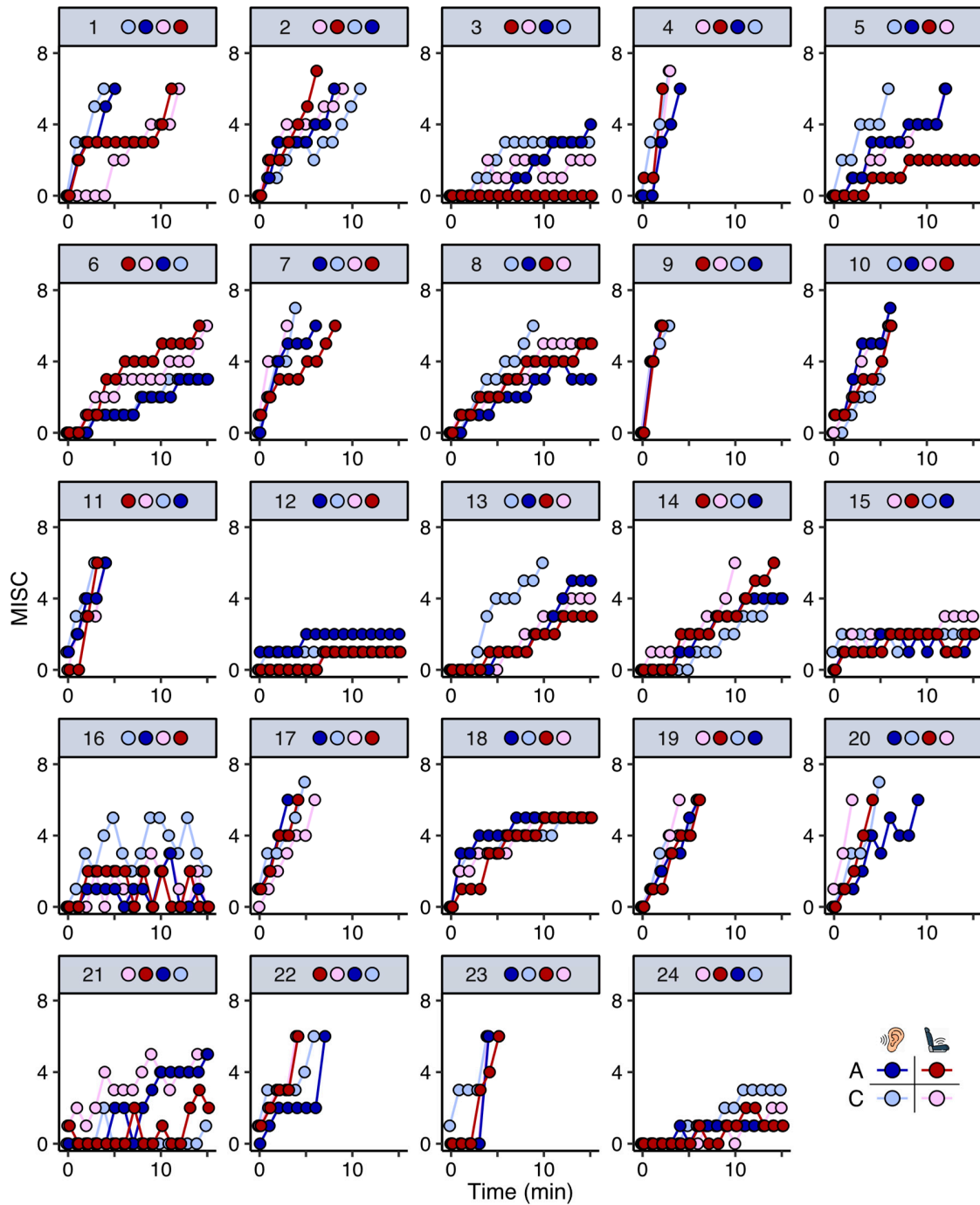


Figure S3. The development of raw MISC scores as a function of time for each session. Darker colors represent the anticipatory (A) sessions and lighter colors the control (C) sessions. Bluish colors indicate the auditory sessions and reddish colors the vibrotactile sessions. Each panel reflects the order of four sessions of a single participant. Participants are ordered according to Figure 3b of the main text.

Reduction values per time point

Expressing the effectiveness of the cue in a single value across all time points becomes meaningful when the cue generates a constant reduction across a session. Below we plot the R values for each of the 15 time points within the auditory and vibrotactile sessions. \bar{R}_t did not vary systematically for either cueing modality, with the 95% confidence intervals overlapping for each time point.

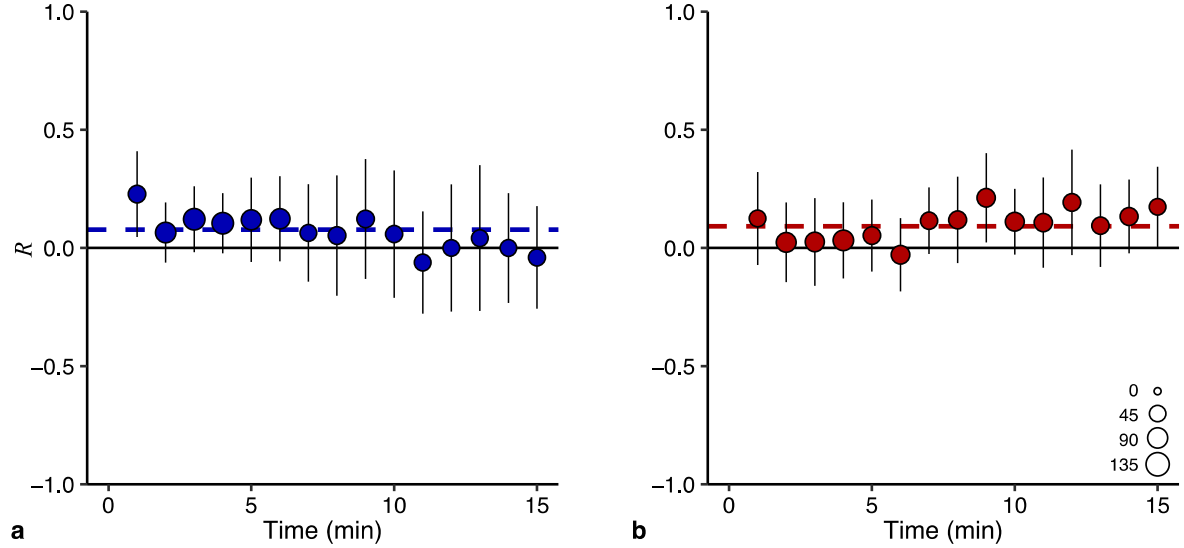


Figure S4. The reduction values for each time point (\bar{R}_t) calculated for the (a) auditory and (b) vibrotactile anticipatory sessions. The lines at zero correspond to no reduction. The dashed lines represent the overall reduction \bar{R} per anticipatory session. The size of the data points reflects the sum of MISC scores underlying the data (see legend). The error bars are 95% confidence intervals calculated with bootstrapping of R_{ti} and corresponding weights.





Additional information on user experience questionnaire

Here, we present additional information obtained from the user experience questionnaire which was not presented in the main text.

First, we also asked participants if they noticed that the cues had always been presented either before or during the motions. This was noticed in all sessions by 71% of participants, in only the auditory sessions by 4%, in only the vibrotactile sessions by 8%, and not at all by 17%.

Second, we also asked participants to rank the cues from most (rank 1; 4 points) to least favorite (rank 4; 1 point) in announcing upcoming motions. The maximum score is 96 (24 participants \times 4 points); the minimum score is 24 (24 participants \times 1 point). We calculated the overall total score per cue (i.e., session) by summing the products (i.e., frequency \times the number of points) of each cell. We then obtain the following ranking across all participants: 1) anticipatory auditory cue, 2) anticipatory vibrotactile cue, 3) auditory control cue, and 4) vibrotactile control cue. Only slightly more participants favored the auditory over the vibrotactile anticipatory cue, suggesting there is no clear preference for one cueing modality.

Table S1. Frequency table on the ranks assigned to each session. The last column represents the resulting end positions (higher values represent a higher preference).

Session	Rank 1	Rank 2	Rank 3	Rank 4	Total score
 A	13	8	2	1	81
 A	10	11	3	0	79
 C	1	4	7	12	42
 C	0	4	12	11	38

Third, we also asked participants how much money they were willing to spend extra on a car that prevents motion sickness. The responses varied greatly, from €0 to €5000, with an average of €778.

Lastly, we also asked participants if they wanted to alter the cue in some aspect. The most frequently given answer was related to personalization of the cues. For example, changing the voice of the auditory cues or using non-speech cues. Other suggestions relating to the vibrotactile cues were to alter its duration, extend the signal to the lower back, and to create a more gradual cueing pattern. No suggestions were made regarding the motion direction the vibrotactile cues indicated. We explicitly mitigated possible ambiguity on this aspect by including a short training session in the experiment (see Procedure). This decision was partly motivated after observing that participants disagreed on the motion direction the vibrotactile cues would indicate in a pilot study (using a different sample). Some participants thought a cue from hip to knee announced a forward motion, while others thought it announced a backward motion. The same ambiguity applied to the cue from knee to hip. This may suggest that some participants relate the directionality of the cue to position in space whereas others relate it to optic flow during self-motion. The results of our pilot test point out that some training on the use of vibrotactile cues is important. Additionally, providing the opportunity to personalize the directionality of the cues could be among the aspects through which the effectiveness of vibrotactile cues may be enhanced.

Development of average MISC scores per session with replacement of missing data

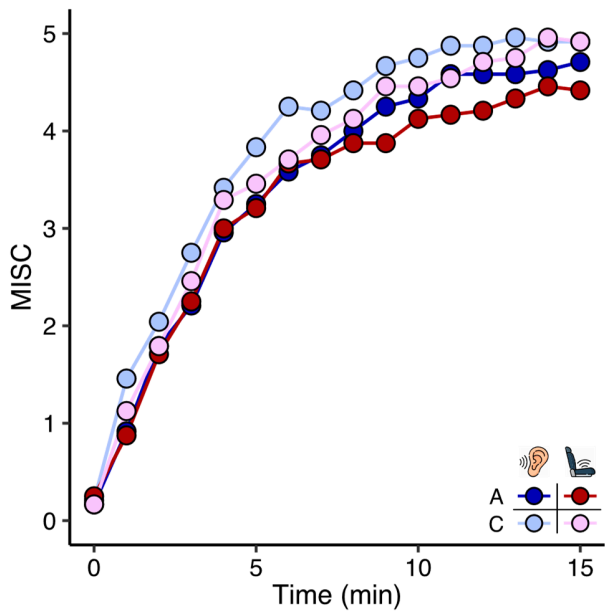


Figure S5. The development of raw MISC scores averaged across participants for each of the four sessions. In contrast to Figure 3a of the main text, we here replaced missing data (as the result of a stop-criterion at $MISC \geq 6$) with the last rated MISC score.