

When Pain Becomes Uncontrollable: An Experimental Analysis of the Impact of
Instructions on Pain-Control Attempts

Pain is an unpleasant sensory and emotional experience that people want to exert control over [9–11]. When acute, exerting such control usually results in the alleviation of pain. Yet when pain becomes largely uncontrollable, such attempts often fail, and persisting in them may fuel suffering and disability [10,26]. Many scholars have sought to explain why people sometimes persistently try to control their pain, despite the maladaptive consequences of doing so [1,18,23]. One line of thought argues that they do so because persistently attempting to control pain has reinforcing consequences and/or prevents them from correcting catastrophic thoughts or expectations concerning pain [14,15,29,31].

Despite much work on this topic [9,21], several questions remain unaddressed. First, few experimental studies have examined pain-control attempts when people lose control over pain [4,10]. This is unfortunate given that losing control over pain is a reality for many patients with chronic pain. Second, research has primarily focused on how actual pain experiences maintain attempts to control uncontrollable pain, but has largely neglected the role of instructions. This is surprising given that verbal processes (particularly instructions) likely explain why certain chronic pain patients persistently seek to control their pain [25].

Research suggests that there are two different categories of instructions that may influence how people adapt to changing situations [19,27], i.e., *plys* and *tracks* [2,22]. *Plys* highlight consequences that will be delivered by the instructor for (non-)compliance with the instruction (e.g., “*if you do not follow my [the dentist’s] recommendation to brush your teeth properly, you will develop serious gum recession which I will have to treat via surgery*”). *Tracks* are instructions that highlight the consequences that naturally occur when the instruction is (not) followed (e.g., “*exercise regularly to improve your overall health*”) [17]. It

is hypothesized that people adhere more to plys compared to tracks, because they have been more frequently reinforced for adhering to plys relative to tracks throughout their lives [22]. Nevertheless, the effects of plys and tracks have not yet been tested in a context where people lose control over pain.

As such, to experimentally examine the effects of plys and tracks on persistent pain-control attempts when people lose control over pain, we conducted three experiments in which participants completed a learning task consisting of two phases. During the first phase, participants were able to exert control over pain, whereas during the second phase they lost control over pain. Prior to the experiment, one group of participants received instructions (i.e., a ply or track) that specified how pain could be controlled, whereas a second group had to discover this strategy via trial-and-error learning. Crucially, the strategy that was described in the instructions was accurate during the first but not the second phase. We hypothesized that when people receive a pain-control strategy from others (i.e., when they receive instructions), they will ‘stick’ to that strategy even when it is no longer effective, compared to when they have to discover the strategy via trial-and-error learning. In addition, we expected this effect to be larger for participants who received a ply as opposed to a track.

Method

Ethical Approval

All experiments described in this manuscript were approved by the Ethics Committee of the Faculty of Psychology and Educational Sciences of Ghent University, Belgium.

Participants and Design

Dutch-speaking volunteers (Experiment 1: $n = 60$; Experiment 2: $n = 60$; Experiment 3: $n = 57$), recruited via an online system at Ghent University, participated in exchange for a monetary reward (Experiment 1: €5; Experiment 2: €10; Experiment 3: €10) or course credits

(Experiment 2). In each experiment, participants were randomly assigned (i.e., via a random sequence generator) to one of three groups: the ply (Experiment 1: $n = 20$; Experiment 2: $n = 20$; Experiment 3: $n = 18$), track (Experiment 1: $n = 20$; Experiment 2: $n = 20$; Experiment 3: $n = 19$), or no-instructions group (Experiment 1: $n = 20$; Experiment 2: $n = 20$; Experiment 3: $n = 20$). See Table 1 for the sample characteristics of Experiments 1-3.

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Materials

Apparatus and Painful Stimuli

All experiments were programmed in Inquisit 4.0, and completed on a Dell Latitude E5530 Notebook. Painful stimuli were electrocutaneous stimuli (ECS) that were delivered via surface electrodes (with stainless steel discs of 10 mm) connected to a constant current stimulator (DS7 Stimulator, Digitimer Ltd, UK). For all participants, these electrodes were attached at the ulnar nerve on the wrist of the non-dominant hand, except for one ambidextrous individual who received the ECS on the right wrist. Stimulus duration of the ECS was 300ms (i.e., 30 cycles of 2ms pulses and an inter-pulse-interval of 8ms).

The intensity of the ECS was individually determined by exposing participants to ECS of increasing intensity (i.e., by using a calibration procedure). In Experiment 1, the ECS intensity was initially set at 1.00mA and increased incrementally by .70mA, upon receiving permission from the participant. Note that during this procedure participants always had the opportunity to decrease the intensity of the ECS. Whenever participants received an ECS they had to rate its intensity on a scale from 0 (*no pain*) to 10 (*worst experienced pain*). Once they indicated that the intensity of an ECS was 7, the calibration procedure ended and this intensity was then used during the Matching-to-Sample (MTS) task [see 5 for a similar calibration procedure]. In Experiment 2 and 3, a similar procedure was used with three exceptions. First,

the calibration procedure now started with an ECS intensity of .00mA, which increased in steps of .50mA. Second, if participants did not perceive a difference between two successive ECS intensities, then the intensity of the next stimuli were increased in steps of 1.00mA in order to reduce the number of stimuli that participants would receive before they initiated the MTS task. Third, whenever participants received an ECS they were asked 1) if it was painful, 2) if it required some effort to tolerate, and 3) whether the experimenter could increase the intensity of the ECS. Once participants replied affirmatively to the first two questions and indicated that they did not want the ECS intensity to increase, the calibration procedure ended and this intensity was then used during the MTS task [see 7-8 for similar calibration procedures].

The average intensity of the ECS that was used during the MTS task was 2.77mA ($SD = .99$ mA) in Experiment 1, 3.69mA ($SD = 1.36$ mA) in Experiment 2, and 3.25mA ($SD = 1.67$ mA) in Experiment 3.

MTS Task

In Experiment 1, the MTS task was a computerized learning task consisting of two phases. Each phase comprised of three blocks of 27 trials. On each trial, participants were presented with four randomly selected images of geometric figures. These images consisted of a 'sample' stimulus and three 'comparison' stimuli. The sample stimulus was always presented at the top of the screen, and the three comparison stimuli were always shown at the bottom left, middle, and right sides of the screen (for an example, see Figure 1). These comparison stimuli always consisted of a stimulus that had many (most-like comparison stimulus), several (moderate-like comparison stimulus), and no features in common (least-like comparison stimulus) with the sample stimulus. A total of 27 sample and 81 comparison stimuli were used.

During the first phase of the task (Blocks 1-3), participants received the written feedback “correct” on 78% and “incorrect” on 22% of the trials whenever they selected the least-like comparison stimulus (LLCS). If they, however, selected one of the other two comparison stimuli, then this was followed by the message “incorrect” on 78% and “correct” on 22% of the trials. Each presentation of the feedback “incorrect” was displayed on a red background and simultaneously presented with an ECS, whereas the message “correct” was always displayed on a green background and never accompanied by an ECS. We decided to partially, rather than completely, reinforce the selection of the LLCS in order to better mimic how pain is encountered in everyday life (i.e., even when pain is controllable it is hardly ever the case that attempts to control it are always effective).

During the second half of the task (Blocks 4-6) an unannounced task-contingency change occurred, such that now participants unexpectedly lost control over pain. Specifically, during this phase, each comparison stimulus selection was followed by the feedback “correct” on 33% and “incorrect” on 67% of the trials. Once again, an ECS was immediately delivered whenever the feedback “incorrect” was displayed, whereas this was never the case when participants saw the message “correct.” In this way there was no longer a response strategy that allowed participants to *maximize* their chances of avoiding an ECS. See Figure 1 for an overview of the MTS task-contingencies during phase 1 and 2 of Experiment 1.

-----INSERT FIGURE 1 HERE-----

In Experiments 2 and 3, a similar MTS task as in Experiment 1 was used with several changes. First, the type of feedback was altered. Specifically, now a blue screen usually indicated that the correct comparison stimulus was selected, whereas a pink screen usually indicated that the incorrect comparison stimulus was selected. By opting for the pink and blue screen, we chose to condition stimuli that did not have well-established meanings, as opposed

to the colors red and green, which often signal something bad/incorrect and good/correct, respectively. Relatedly, we omitted the onscreen feedback “correct” and “incorrect” that were used in Experiment 1. We did so because there could have been a possibility that participants in Experiment 1 interpreted the messages “correct” presented on a green screen and “incorrect” presented on a red screen, as indicators of whether they succeeded and failed to behave in line with what the experimenter wanted, respectively. Second, the number of ECS that could be delivered was halved in order to reduce the probability that participants would habituate to the ECS. As such, whenever a pink screen was shown, this was followed by an ECS on 50% of the trials (after an inter-stimulus interval [ISI] of 2000ms). Third, because the number of ECS were halved, each experimental block now consisted of 30 trials. As a result the stimulus pool comprised of 30 images of geometric figures that functioned as sample stimuli and 90 such images that were used as comparison stimuli. Finally, given the number of trials during each experimental block, the task-contingencies during the first phase (Blocks 1-3) were also modified. Specifically, now selecting the LLCS was followed by a blue screen on 80% and a pink screen on 20% of the trials, whereas selecting one of the other two comparison stimuli was followed by a blue screen on 20% and a pink screen on 80% of the trials. For an overview of the MTS task-contingencies during phases 1 and 2 of Experiments 2 and 3, see Figure 2.

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Instructions

In Experiment 1, participants received general information about the MTS task. For those in the ply and track groups this information was as follows:

“You are participating in an experiment that investigates your ability to match stimuli.

Throughout the task, you will always be presented with four images consisting of an

exemplar and three alternatives. Your task is to select the alternative that differs the most from the exemplar.”

The no-instructions group received similar information except for the fact that they were not informed about the specific comparison stimulus that they should select in order to avoid the ECS. Indeed, they were told “Your task is to select the correct alternative” as opposed to “Your task is to select the alternative that differs the most from the exemplar.”

After presenting the above information, participants in the ply and track groups received an additional unique instruction. Those in the ply group were told:

“I (the researcher) will monitor your performance throughout the task. If you fail to follow my precise instructions, there is a chance I will give you a painful stimulus.”

We assumed that this instruction would function as a ply because it informed participants that the consequence for non-adherence to the instructions (i.e., an ECS) would be delivered by the instruction-giver (i.e., the experimenter). Similar to previous research on this topic, this instruction also informed participants that their performances would be monitored by the experimenter [2, 18, 20].

Those in the track group were told that:

“The task is programmed in such a way that if you fail to select the alternative that differs the most from the sample, you have a larger chance of receiving a painful stimulus.”

We reasoned that this instruction would function as a track because it described consequences for non-compliance that were determined by the way the task was designed. The no-instructions group did not receive any of the additional instructions.

Note that during phase 1, the instructions delivered to the ply and track groups largely corresponded with the task-contingencies whereas those same instructions were unrelated to the task-contingencies during phase 2. Put simply, adherence to these instructions allowed participants to maximize their control over pain during phase 1 but not phase 2.

Finally, the aforementioned general information and additional instructions were delivered prior to the onset of the learning (MTS) task, and participants were requested to repeat the instructions before completing each experimental block.

In Experiments 2 and 3, the general information of the MTS task was expanded such that participants did not only receive the same general information as in Experiment 1 but were also told:

“Whenever you select an alternative you will see a pink or a blue screen. If you see a pink screen, this means there is a chance you will receive a painful stimulus. If you see a blue screen, this means you will not receive a painful stimulus.”

In Experiment 3, the general information additionally included the following piece of information:

“If you see a pink screen, this usually means you selected the wrong alternative. If you see a blue screen, this usually means you selected the correct alternative.”

Once again, after receiving the general information about the MTS task, the ply and track groups of Experiments 2 and 3 received unique instructions. These instructions were similar to those used in Experiment 1, except for the fact that the ply and track groups of Experiments 2 and 3 were additionally told that a pink screen would be shown if they did not follow the experimenter’s instruction (ply group) or selected the least-like comparison stimulus (track group). As in Experiment 1, the no-instructions groups of Experiments 2 and 3

did not receive such unique instructions and had to learn about the task-contingencies via trial-and-error.

To enhance the credibility of the unique instructions, in Experiments 2 and 3, the experimenter (the first author or a male undergraduate psychology student) gave the following oral information. In the ply group, s/he told participants that s/he would monitor their task performances via the one-way observation screen. In the track and no-instructions groups, the experimenter told participants that s/he would be working in another room while they completed the experiment, and that they should only contact her/him if they completed the experiment or encountered technical problems. As in the previous experiment, the general information and unique instructions used in Experiments 2 and 3 were delivered before participants initiated the MTS task, and participants in the ply and track groups of both experiments were asked to describe these instructions prior to each experimental block.

Post-Session Questions

In each experiment, participants were asked two open-ended questions after completion of the MTS task: “*What do you think the experiment was about?*” and “*Which strategies did you use during the task?*” In all experiments, these questions were followed by a number of closed-ended questions to explore how participants experienced certain aspects of the experiment.

In Experiment 1, participants were, specifically, asked to rate how important it was for them to comply with the instructions (ply and track groups) or the strategies that they developed themselves (no-instructions group) (from 1 = *not important* to 6 = *very important*). They were also asked to rate the ECS in terms of its intensity (from 1 = *not painful* and 6 = *very painful*) and how irritating it was for them (from 1 = *not irritating* to 6 = *very irritating*).

Finally, the ply group was also asked to rate the trustworthiness of the experimenter (from 1 = *not trustworthy* to 6 = *very trustworthy*).

In Experiments 2 and 3, participants were also asked to rate the intensity of the ECS, how unpleasant the ECS was for them, the extent to which they felt they could avoid the ECS, and how anxious or nervous they were during the experiment, using an 11-point Likert scale (from 0 [*absolutely not*] to 10 [*very much*]). Importantly, in Experiment 3, participants were asked to first answer the closed questions after phase 1 (Blocks 1-3) and then phase 2 (Blocks 4-6). Participants were then orally asked whether they noticed any change during the MTS task (*“Did you notice any change during the experiment?”*). If they did, they were asked to indicate on a sheet of paper which of the following statements reflected their thoughts about the change the most: (a) *“In the first part of the task selecting the least-like comparison stimulus was usually considered correct. In the second half of the task this was no longer the case”*; (b) *“In the first part of the task I could receive a painful stimulus after seeing a pink but not a blue screen. In the second half of the task, this was no longer the case”*; (c) *“In the first part of the task a blue screen usually indicated that I made the right choice. In the second part of the task this was no longer the case”*; or (d) *“none of the above.”* If participants selected alternative (d), then they were asked to report what they thought changed instead. In the cases where participants did not report being aware of any changes, the experimenter informed them that something did in fact change. Participants were then asked to read statements a, b, and c and to select what they thought reflected the task-contingency change. Once again, these questions served an exploratory purpose. All post-session questions were included for exploratory purposes.

Procedure

In each of the experiments, upon arrival, participants were welcomed by the researcher in a university research room (280 x 280 cm) which had two tables (160x80cm and 80x80cm) and two chairs. Participants were then seated in front of a laptop and provided with a brief description of the experiment. Once they gave their written informed consent, the calibration procedure was initiated. After this procedure, the experimenter instructed participants to initiate the MTS task before s/he left the research room. Note that in Experiment 1, the research room was a standard experiment room. In Experiments 2 and 3, however, participants in the ply group completed the experiment in a research room with a one-way observation screen, whereas those in the track and no-instructions groups did so in a standard experiment room (i.e., without a one-way observation screen). This manipulation was included to increase the probability that participants would believe that the experimenter was monitoring their behavior (i.e., it was included to add more credibility to the ply). Critically, before participants completed the MTS task in Experiments 3, the experimenter also typed their first name (in the ply group) or “xxxx” (in the track and no-instructions groups) on the computer screen. Our argument here was that if we gave participants the impression that the experimenter could (in the ply group) or could not (in the track and no-instructions groups) track their task performances we could add further credibility to the ply and track instructions. In each of the experiments, after completion of the MTS task, participants were asked to answer the post-session questions and were debriefed.

Data Collection -and Analysis

All data were collected without intermittent data analysis. To test our hypotheses, we used the following analytic strategy. First, in each experiment, we assessed whether participants responded in line with the task-contingencies operating during the first phase of the MTS task (i.e., whether they selected the least-like comparison stimulus; LLCS). We,

specifically, did so because we reasoned that if we want to examine how people adapt to changes in the effectiveness of previously effective pain-control strategies, it is important that they relied on these strategies prior to this change. We used a one-tailed exact binomial test to determine when behavior was in line with the task-contingencies during the first phase. Specifically, during Block 3, we assessed on how many trials participants would have to select the LLCS before it could be argued that their behavior was non-random (i.e., controlled by the task-contingencies). We focused on this block because we reasoned that by then, participants would have had enough opportunities to learn about the task-contingencies of the first experimental phase.

Next, for each experiment, we tested whether the probability of selecting the LLCS during the second phase (Blocks 4–6) was influenced by group membership (i.e., Instructions Group: ply, track or no- instructions group). This was achieved using a binomial generalized linear mixed model (BGLMM) with a logit link function and a random intercept for subjects in R-version 3.4.0. It is worth noting that during the second phase (Blocks 4-6) we concluded that behavior was in line with task-contingencies of the first phase (Blocks 1-3) if the probability of selecting the LLCS was larger than .33. In addition, some experiment-specific analyses were conducted.

For experiment 1, a series of one-way ANOVA's were carried out with Instructions Group as the independent variable to test for differences between the ply, track, and no-instructions groups' self-reports of how intense and irritating they perceived the ECS. In addition, *t*-tests were conducted to test for differences between the ply and track groups regarding the importance they placed on complying with the instructions. For Experiment 2, a series of one-way ANOVA's with Instructions Group as the independent variable were carried out for participants' answers to the closed questions. Finally, regarding Experiment 3, a series of repeated measures ANOVA's with Instructions Group and Phase (Phase 1: Blocks

1-3, Phase 2: Blocks 4-6) as independent variables were carried out for participants' answers to the closed questions. All analyses of participants' answers to the self-report measures, were carried out in SPSS version 25.

Alpha was set at .05 for all statistical tests and contrasts were always calculated using dummy coding. Furthermore, effect sizes are reported using either Cohen's *d*, the eta-squared statistic or the area under the curve (AUC). The AUC is an index of the discriminating ability of a test [13]. Within the current context, the AUC informs us about how well a variable can discriminate between participants that followed the rule and those that did not. Interpretations of the AUC of a main effect should be made by comparing this AUC with the AUC of the intercept model (.50). If a variable for which a main effect was observed has an AUC of .50, this means that it cannot discriminate between participants that followed the rule and those that did not. If this variable has an AUC of 1.00, this mean it can perfectly discriminate between the aforementioned groups. The AUC for an interaction effect, however, is obtained by subtracting the AUC of the full model (Experiment 2: .74, Experiment 3: .77) from the AUC of the model with only the main effect (Experiment 2: .73, Experiment 3: .76). The larger this value, the better the interaction effect can discriminate between participants that followed the rule and those that did not.

Data Storage

The general information, instructions, and post-session questions that were used in Experiments 1-3 were designed in Dutch, and translated into English for the current manuscript. Access to the Dutch versions as well as the data and analytic scripts can be obtained via the Open Science Framework (<https://osf.io/wh9ak/>).

Results

Learning Criterion

The one-tailed exact binomial test revealed that, in Experiment 1, non-random behavior required that participants selected the LLCS on at least 14 out of the 27 trials during Block 3. In Experiment 2 and 3, however, the results of the one-tailed exact binomial test suggested that non-random responding equaled selecting the LLCS on at least 15 out of the 30 trials during Block 3.

In Experiment 1, one participant from the ply group and two from the no-instructions group failed to meet the learning criterion and were therefore excluded. This left a final sample of 57 participants for subsequent analyses ($M_{age} = 23$ years; $SD = 3.79$; 46 women). On average, participants selected the LLCS on 25 out of the 27 trials of Block 3 (ply group: $M = 26$ [96%], $SD = 1$ [4%]; track group: $M = 26$ [96%], $SD = 1$ [4%]; no-instructions group: $M = 24$ [89%], $SD = 4$ [15%]). Further analyses revealed no difference between the ply and track groups regarding their probability of selecting the LLCS during Block 3, $t(37) = .23$, $p = .82$. Participants in the no-instructions group, however, did select the LLCS significantly less than their counterparts in the ply, $t(19.10) = 3.15$, $p < .01$, $d = .71$, 95% CI of $d = [-3.92, -.08]$, and track groups during Block 3, $t(19.66) = 3.04$, $p < .01$, $d = .72$, 95% CI of $d = [-3.87, -.13]$.

In Experiment 2, two participants failed to meet the learning criterion: one from the track and one from the no-instructions group, and were thus excluded from the analyses. The data from one participant in the ply group of Experiment 2 was also removed due to technical problems with the DS7 stimulator. This left a final sample of 57 participants ($M_{age} = 20$ years, $SD = 3.53$, 43 women) of which data were used for the analyses. On average, in Experiment 2, participants selected the LLCS on 28 out of the 30 trials of Block 3 (ply group: $M = 30$ [100%], $SD = 1$ [3%]; track group: $M = 29$ [97%], $SD = 2$ [6%], no-instructions: $M = 26$

[87%], $SD = 5$ [17%]). Similar results were observed as in Experiment 1 when comparing these groups' probability of selecting the LLCs during Block 3 (i.e., no difference was observed between the ply and track groups, $t(36) = .21$, $p = .84$, and the no-instructions group selected the LLCs significantly less compared to the track, $t(23.47) = 2.69$, $p < .05$, $d = .81$, 95% CI of $d = [-5.51, -.49]$, and ply groups, $t(18.93) = 2.94$, $p < .01$, $d = 1.14$; 95% CI of $d = [-6.37, -1.63]$).

In Experiment 3, three participants from the no-instructions group did not behave in line with the task-contingency during Block 3. Hence, 54 participants ($Age = 22$, $SD = 3.11$, 40 women) who, on average, selected the LLCs on 29 of 30 trials of Block 3 (ply group: $M = 30$ [100%], $SD = 0$ [0 %], track group: $M = 30$ [100%], $SD = 0$ [0 %], no-instructions group: $M = 27$ [90%] $SD = 5$ [17 %]) were included in subsequent analyses. Similar to Experiments 1 and 2, no significant difference was observed between the ply and track groups, $t(27.41) = 27.41$, $p = .09$, and the no-instructions group selected the LLCs significantly less than those in the track, $t(16.25) = -2.29$, $p < .05$, $d = .90$, 95% CI of $d = [-5.33, -.67]$, and ply groups, $t(16.07) = -2.48$, $p < .05$, $d = .89$, 95% CI of $d = [-5.40, -.60]$.

Note that participants' performance during Block 3 was not included in subsequent hypotheses tests, because (a) hypotheses tests with this variable did not additionally explain the variance in their responding during the second phase (Experiment 1) or (b) a lack of variance in participants' performances during Block 3 prevented us from controlling for this variable when testing our hypotheses (Experiments 2 and 3).

Hypotheses Testing

In all experiments, analyses indicated that participants were highly likely to continue selecting the LLCs after the task-contingency change took place between phases 1 and 2 (see the supplementary material). Across all experiments, this tendency appeared to vary as a

function of Instructions Group (Experiment 1: $\chi^2(2) = 24.56, p < .001, AUC = .60$; Experiment 2: $\chi^2(2) = 32.20, p < .001, AUC = .73$; Experiment 3: $\chi^2(2) = 29.22, p < .001, AUC = .76$). A series of contrast analyses revealed that in all experiments, participants who were given any type of instruction, i.e., a ply or a track, were more likely to select the LLCS compared to those that did not receive instructions (Experiment 1: ply vs no-instructions: $\chi^2(1) = 24.43, p < .001$; track vs no-instructions: $\chi^2(1) = 4.90, p < .05$; Experiment 2: ply vs no-instructions: $\chi^2(1) = 22.32, p < .001$; track vs no-instructions: $\chi^2(1) = 22.36, p < .001$; Experiment 3: ply vs no-instructions: $\chi^2(1) = 16.11, p < .001$; track vs no-instructions: $\chi^2(1) = 27.45, p < .001$). In Experiment 1, this was especially the case for those who received a ply compared to a track, $\chi^2(1) = 8.21, p < .01$. No such difference was observed in Experiment 2, $\chi^2(1) = .01, p = .92$, and Experiment 3, $\chi^2(1) = 1.50, p = .22$.

Furthermore, in Experiment 1, a main effect of Block Type was found ($AUC = .52$) which indicated that participants had a larger probability of selecting the LLCS in Block 4 compared to Block 5. No such difference was observed in Block 5 compared to Block 6. No effect of Block Type was observed in Experiments 2 ($AUC = .51$) and 3 ($AUC = .52$).

Finally, a significant two-way interaction between Instructions Group and Block Type also emerged in Experiment 2 ($AUC = .01$) and Experiment 3 ($AUC = .00$), but not Experiment 1 ($AUC = .00$). Follow-up contrast analyses revealed that in Experiments 2 and 3, participants in the ply group were more likely to select the LLCS compared to their counterparts in the no-instructions group during Block 4, Block 5, and Block 6. Participants in the track group were also more likely to do so than those in the no-instructions group during Block 4, Block 5, and Block 6 as well. Nevertheless, the track and ply groups did not differ in the extent to which they were inclined to select the LLCS after the task-contingency change, in either Block 4, Block 5, or Block 6. See Figure 3 for an overview of the estimated probability of selecting the LLCS as a function of Instructions Group and Block Type, and the

corresponding 95% confidence intervals for Experiments 1-3. The inferential statistics for the effect of Block Type, and the interaction between Instruction Type and Block Type can be found in Table 2.

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-----INSERT TABLE 2 HERE-----

Self-Report Measures

Open-Ended Questions

Results showed that, in each of the experiments, approximately half of the participants accurately reported one of the study objectives (i.e., to examine the impact of pain on learning or participants' adaptation to task-contingency changes, or the impact of instructions on behavior). Of these participants, however, only a very small number reported that the experiments examined the impact of instructions on their behavior and none reported that the experiments examined the differential impact of plys and tracks. Furthermore, when asked to report the strategy that they used during the task, most participants reported that this was usually or always selecting the LLCS. See Table 3 for an overview of the number of participants that reported 1) that the experiment examined the impact of instructions on their behavior, 2) that the experiment examined the impact of pain on learning or how people adapt to task-contingency changes, and 3) that they usually or always selected the LLCS.

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Closed Questions

The results of Experiment 1 revealed no difference between the ply and track groups' ratings of how important it was for them to follow the instructions they received, $t(1.23, 37) = .84, p = .28$ (ply group: $M = 4.58, SD = 1.35$; track group: $M = 4.50, SD = 1.05$). In addition, no difference was observed between the ply, track, and no-instructions groups with regard to

their pain intensity ratings, $F(2, 56) = 1.70, p = .19$ ($M_{\text{range}}: 3.74 - 4.22$). Finally, similar results were observed for their ratings of how irritating they perceived the ECS, such that no differences were observed between the three groups, $F(2, 56) = .80, p = .45$ ($M_{\text{range}}: 4.32 - 4.75$).

The results of Experiment 2 showed that the ply, track, and no-instructions groups did not differ with regard to their ratings of the intensity, $F(2, 56) = 2.20, p = .12$ ($M_{\text{range}}: 5.11 - 6.11$), unpleasantness, $F(2, 56) = .98, p = .38$ ($M_{\text{range}}: 5.89 - 6.68$), and controllability of the ECS, $F(2, 56) = .24, p = .79$ ($M_{\text{range}}: 2.04 - 3.22$). Similar results were observed when comparing their anxiety ratings, such that we also did not find a difference between the groups, $F(2, 56) = .54, p = .59$ ($M_{\text{range}}: 3.84 - 4.53$).

In Experiment 3, no significant effects were found of the independent variables Instructions Group and Experimental Phase, on participants' ratings of the intensity ($F \leq 3.38, ns; M_{\text{range}}: 5.79 - 6.47$) and unpleasantness of the ECS (all $F \leq 1.78, ns; M_{\text{range}}: 6.88 - 7.33$). However a main effect of Experimental Phase did emerge with regard to perceived control over ECS delivery, $F(1, 51) = 38.60, p < .001, \eta^2 = .43$, suggesting that participants felt more in control in phase 1 ($M = 4.52, SD = 2.86$) compared to phase 2 ($M = 2.07, SD = 2.16$). The main effect for Instructions Group, $F(2, 51) = .21, p = .81$, and the interaction effect between Instructions Group and Experimental Phase, $F(2, 51) = .39, p = .68$, were not significant. Likewise, for participants' ratings of how anxious they were during the task, no main effect of Instructions Group, $F(2, 51) = .61, p = .55$, nor an interaction effect between this variable and Experimental Phase were observed, $F(2, 51) = .83, p = .44$. The main effect of Experimental Phase was, however, significant, $F(1, 51) = 9.20, p < .01, \eta^2 = .15$, suggesting that participants became increasingly anxious after the pain stimulus became uncontrollable (Blocks 1-3: $M = 4.59, SD = 2.45$; Blocks 4-6: $M = 5.19, SD = 2.93$).

Moreover, the results of Experiment 3 revealed that 41 participants answered affirmatively to the question as to whether they noticed any change during the experiment (ply group: $n = 14$ [78% of the total ply group], track group: $n = 16$ [84% of the total track group], no-instructions group: $n = 11$ [65% of the total no-instructions group]). Yet no differences were observed between these groups, $F(2, 50) = .18, p = .33$. Of these participants, 39 indicated what they thought the change implied (ply group: $n = 13$, track group: $n = 15$, no-instructions group: $n = 11$). For 28 of these participants the statement that reflected their thoughts about the change was (a) (i.e., “In the first part of the task selecting the least-like comparison stimulus was usually considered correct. In the second half of the task this was no longer the case”) (ply group: $n = 6$, track group: $n = 12$, no-instructions group: $n = 10$). Furthermore, eight out of the 13 remaining participants who did not report noticing any change during the experiment also thought statement (a) reflected the contingency change (ply group: $n = 4$, track group: $n = 3$, no-instructions group: $n = 6$).

Discussion

A regularly observed phenomenon is that when pain becomes largely uncontrollable, people often try to control it. Although doing so is useful when pain-control can be achieved, tenacious attempts to control largely uncontrollable pain can lead to increased suffering and disability [23,24,30]. While we know that persistent attempts to control pain can arise on the basis of actual pain experiences [28] relatively little is known about: how the *loss* of control over pain impacts such attempts and what the role is of (different) instructions in this regard.

To fill in these gaps, we conducted three experiments in which participants were confronted with a learning task wherein they could initially control pain, but then unexpectedly lost control over pain. Prior to the task, some participants were provided with a pain-control instruction (either a ply or track) which, if followed, initially allowed them to

control pain. Others received no such instructions and thus had to develop their own pain-control strategies (via trial-and-error learning). We had two main hypotheses. First, we anticipated that when participants lost control over pain, they would be more inclined to follow the previously effective pain-control strategy if they received pain-control instructions as opposed to when they did not receive these instructions. Second, we hypothesized that this effect would be stronger when participants received a ply as opposed to a track.

In all three experiments, repeated evidence emerged in line with our first hypothesis. When pain could no longer be controlled, the instructions groups were more likely to adhere to the previously effective pain-control strategies compared to the no-instructions groups. Interestingly, under the same circumstances, the no-instructions groups also did not completely abandon the previously effective pain-control strategies. Several possible explanations present themselves. One possibility is that the behavior of the no-instructions groups was not solely governed by the task-contingencies, but also by self-developed pain-control instructions. If so, then our findings can be reformulated in the following way: when humans are not provided with pain-control instructions, they generate their own and tend to stick to these even when they are no longer maximally effective. This tendency, however, appears to be smaller as compared to when pain-control instructions are provided by others.

Alternatively, it may be that the no-instructions *and* instructions groups' tendency to stick to the previously effective pain-control strategies, was due to certain task-features. For example, it is possible that after the unexpected change in the task-contingencies, participants were inclined to stick to these strategies because they had no other means of effectively controlling pain. It could also be that participants were likely to stick to the previously effective pain-control strategies because doing so did not bring along significant costs. Indeed, past work on the effects of competing goals on pain-control has shown that when

there are no real costs associated with pain-control, people are more likely to demonstrate such behavior compared to instances in which pain-control brings along significant costs [8,12].

However, given that we did not systematically examine the aforementioned hypotheses we recommend future work to examine them. We propose several ways in which this can be done. For example, to gain online-insight into potential strategies or instructions that people developed and followed during our MTS tasks, a ‘think-aloud’ procedure could be used [6]. Furthermore, to investigate whether participants’ tendency to stick to the previously effective pain-control strategies was *because* they lost control over pain, future work could include a comparison group that can still control pain after the task-contingency change. Finally, to examine if costs for adhering to previously effective pain-control strategies attenuate future attempts to stick to these strategies, future studies could include a condition where sticking to these strategies decreases participants’ chances of accessing a valued outcome (e.g., a monetary reward).

Experiment 3 highlights the possibility that people’s tendency to persistently stick to previously effective pain-control strategies when faced with uncontrollable pain may have been a conscious decision. That is, they stuck to what worked in the past despite *knowing* that doing so was no longer effective. This raises an important question: why do people continue to avoid largely uncontrollable pain in ways that worked in the past - even if they know that doing so is no longer useful? In addition to the above suggestions, it might be that they did so as a means to achieve their goal of being perceived as a good participant. That is, that they continued to apply the previously effective pain-control strategy because they thought that was what the experimenter wanted [20]. However, given that we did not directly examine this possibility, further research is warranted to assess the validity of this idea.

Similar to past work with non-painful stimuli [2,19,22], evidence for our second hypothesis (i.e., that adherence to plys would result in more persistent pain-control attempts than tracks) was ambiguous. Although we obtained initial support for this hypothesis in Experiment 1, no such evidence emerged in Experiments 2-3. Three possible factors may explain these divergent findings. First, unlike Experiment 1, we observed ceiling effects in the ply and track groups in Experiments 2-3. This may have stemmed from the specificity of the pain-control instructions delivered in these experiments. Indeed, past work suggests that when instructions are no longer effective, people have more difficulties abandoning these instructions if they are specific (i.e., if they specify the exact conditions under which particular consequences will be delivered) rather than general (i.e., if they only describe the consequences of behavior) [16]. It may be that by including information about what participants could expect after seeing the pink and blue screens in Experiments 2-3, and what these screens meant in Experiment 3, we created highly specific instructions which resulted in strong adherence to them and thus potentially overrode the effects of the plys and tracks.

Second, unlike Experiment 1, in Experiments 2-3 we omitted the messages “correct” and “incorrect” as consequential stimuli because of their potentially ambiguous nature. Nonetheless, if during an MTS task, people generally interpret “correct” and “incorrect” in terms of their behavior during the task, then it could be that the ceiling effects of Experiments 2 and 3 were due to the fact that participants were not as strongly prompted to explore alternative strategies. Indeed, it could be that abandonment of previously effective pain-control strategies is more likely if people are more frequently told that their old strategies are no longer effective.

Third, we may have failed to find consistent differences between the ply and track groups in Experiments 2-3 because the plys and tracks that people follow in the real life differ

on other dimensions than those manipulated in the current experiments. For instance, it might be that in everyday life - when pursuing long-term goals - people often follow plys, whereas tracks are rather followed when obtaining short-term goals [3]. Arguably, this may be because when people try to achieve challenging goals, adhering to instructions that describe speaker-mediated consequences for adhering to them might increase chances of success (e.g., when patients follow an instruction such as “If I adhere to my therapist’s health recommendations, he will praise me”). Particularly, seeing as the consequences for following such instructions (e.g., praise) can serve as additional sources of reinforcement, which might help overcome the potentially interfering effects of certain events (e.g., relapse) on the achievement of long-term goals. However, in the case of short-term goals (e.g., contacting a therapist by tomorrow) one could argue that tracks might be more appropriate, given that there are relatively fewer obstacles that can emerge during such time-frames.

We recommend future work to examine the extent to which the above three factors contributed to our inability to find a consistent difference between the ply and track groups. This can be done by a) investigating the moderating impact of the specificity vs. generality of plys and tracks, b) examining the moderating impact of the messages “correct” and “incorrect” vs. no such messages on persistent pain-control attempts, and c), using methodologies (e.g., the diary methodology) allowing to gain insight into the type of pain-control instructions that people follow in daily life.

This study has some limitations. First, students mainly served as participants and we used short-lived pain (elicited via ECS) which limits the generalizability of the current findings to chronic pain patients. Second, we did not include a group that lost control over non-painful stimuli. As such, we cannot conclude whether our findings are unique to pain. Third, relatively small samples were used in all studies, which might have resulted in low

statistical power. Fourth, we did not examine if participants believed that pain was either a consequence of the task (in the track groups) or contingent upon the actions of the experimenter (in the ply groups), which makes it difficult to fully determine the success of our instruction manipulations. Finally, due to our relatively small sample sizes we were unable to examine whether participants' awareness of our study objectives impacted their performances.

Acknowledgments:

The authors want to thank Gregory Verleysen and Maarten De Schryver for the statistical support. This work was supported by the Ghent University Grant BOF16/MET_V/002 that was awarded to Jan De Houwer. The authors have nothing to disclose.

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Figure legends

Fig. 1. Overview of the Matching-To-Sample (MTS) task-contingencies during Blocks 1-6 of Experiment 1.

Fig. 2. Overview of the Matching-To-Sample (MTS) task-contingencies during Blocks 1-6 of Experiments 2 and 3.

Fig. 3. Estimated probability (π) of selecting the LLCs as a function of Instructions Group (ply, track, and no-instructions) and Block Type (Blocks 4, 5, and 6), and 95 % confidence intervals (CI) in Experiments 1, 2, and 3.

Table 1***Sample characteristics of Experiments 1-3.***

	Experiment 1	Experiment 2	Experiment 3
Age	<i>M</i> = 23 (<i>SD</i> = 3.76)	<i>M</i> = 20 (<i>SD</i> = 3.00)	<i>M</i> = 22 (<i>SD</i> = 3.07)
Ratio women:men	49:11	46:14	43:14
Occupation			
Student	n = 54	n = 55	n = 53
Clerk	n = 2	n = 3	n = 3
Unemployed	n = 3	n = 2	n = 1

Note. In Experiment 1 the demographic data of one participant was missing. As such the reported values of Experiment 1 are based on the 59 participants of which demographic data were available.

Table 2

Inferential statistics for the effect of Block Type, and the interaction between Instruction Type and Block Type in Experiments 1-3

	Experiment 1		Experiment 2		Experiment 3	
	<i>P</i> value	Test Statistic	<i>P</i> value	Test Statistic	<i>P</i> value	Test Statistic
Block Type Effect	< .01	$\chi^2(2) = 7.84$	= .88	$\chi^2(2) = .26$	= .69	$\chi^2(2) = .75$
Block 4 vs 5	< .01	$\chi^2(1) = 5.25$	= .08	$\chi^2(1) = .78$	= .41	$\chi^2(1) = .67$
Block 4 vs 6	< .01	$\chi^2(1) = 6.51$	= .25	$\chi^2(1) = .62$	= .92	$\chi^2(1) = .01$
Block 5 vs 6	= .79	$\chi^2(1) = .07$	= .05	$\chi^2(1) = .82$	= .48	$\chi^2(1) = .50$
Instruction Type * Block Type Effect	= .46	$\chi^2(4) = 3.61$	< .001	$\chi^2(4) = 30.22$	< .001	$\chi^2(4) = 29.80$
<i>Block 4</i>						
Ply vs. No-instructions	< .001	$\chi^2(1) = 23.24$	< .001	$\chi^2(1) = 22.67$	< .01	$\chi^2(1) = 8.82$
Track vs. No-instructions	= .06	$\chi^2(1) = 3.54$	< .001	$\chi^2(1) = 14.62$	< .001	$\chi^2(1) = 16.87$
Ply vs. Track	< .001	$\chi^2(1) = 9.51$	= .39	$\chi^2(1) = .74$	= .25	$\chi^2(1) = 1.30$
<i>Block 5</i>						
Ply vs. No-instructions	< .001	$\chi^2(1) = 13.53$	< .001	$\chi^2(1) = 20.27$	< .001	$\chi^2(1) = 20.71$
Track vs. No-instructions	= .08	$\chi^2(1) = 3.15$	< .001	$\chi^2(1) = 29.18$	< .001	$\chi^2(1) = 31.04$
Ply vs. Track	< .05	$\chi^2(1) = 4.03$	= .32	$\chi^2(1) = 1.00$	= .29	$\chi^2(1) = 1.13$
<i>Block 6</i>						
Ply vs. No-instructions	< .001	$\chi^2(1) = 22.65$	< .001	$\chi^2(1) = 21.36$	< .001	$\chi^2(1) = 17.99$
Track vs. No-instructions	< .05	$\chi^2(1) = 5.40$	< .001	$\chi^2(1) = 22.03$	< .001	$\chi^2(1) = 30.37$

Ply vs. Track	< .01	$\chi^2(1) =$ 6.67	= .88	$\chi^2(1) =$.02	= .19	$\chi^2(1) =$ 1.72
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Table 3***Results open-ended questions***

	Experiment 1	Experiment 2	Experiment 3
Report 1			
Ply group	8	1	1
Track group	6	2	1
No-instructions group	0	0	0
Report 2			
Ply group	5	6	10
Track group	8	7	10
No-instructions group	7	13	11
Report 3			
Ply group	14	9	9
Track group	11	9	14
No-instructions group	6	3	4

Note. Report 1 refers to the number of participants that stated that the experiment examined the impact of instructions on their behavior. Report 2 refers to the number of participants that reported that the experiment examined the impact of pain on learning or how people adapt to task-contingency changes. Report 3 refers to the number of participants that reported that they usually or always selected the least-like comparison stimulus.

FIGURE 1

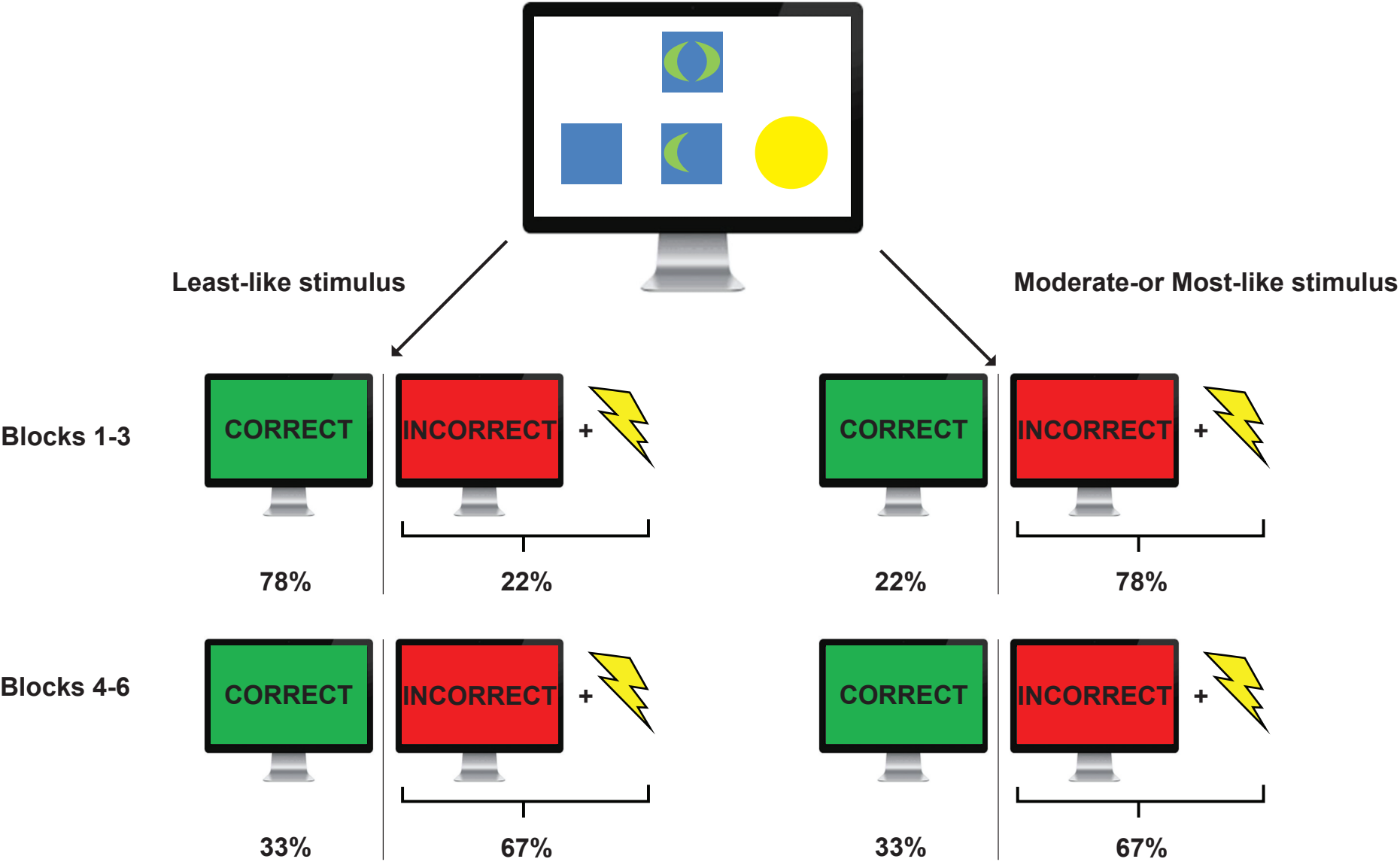


FIGURE 2

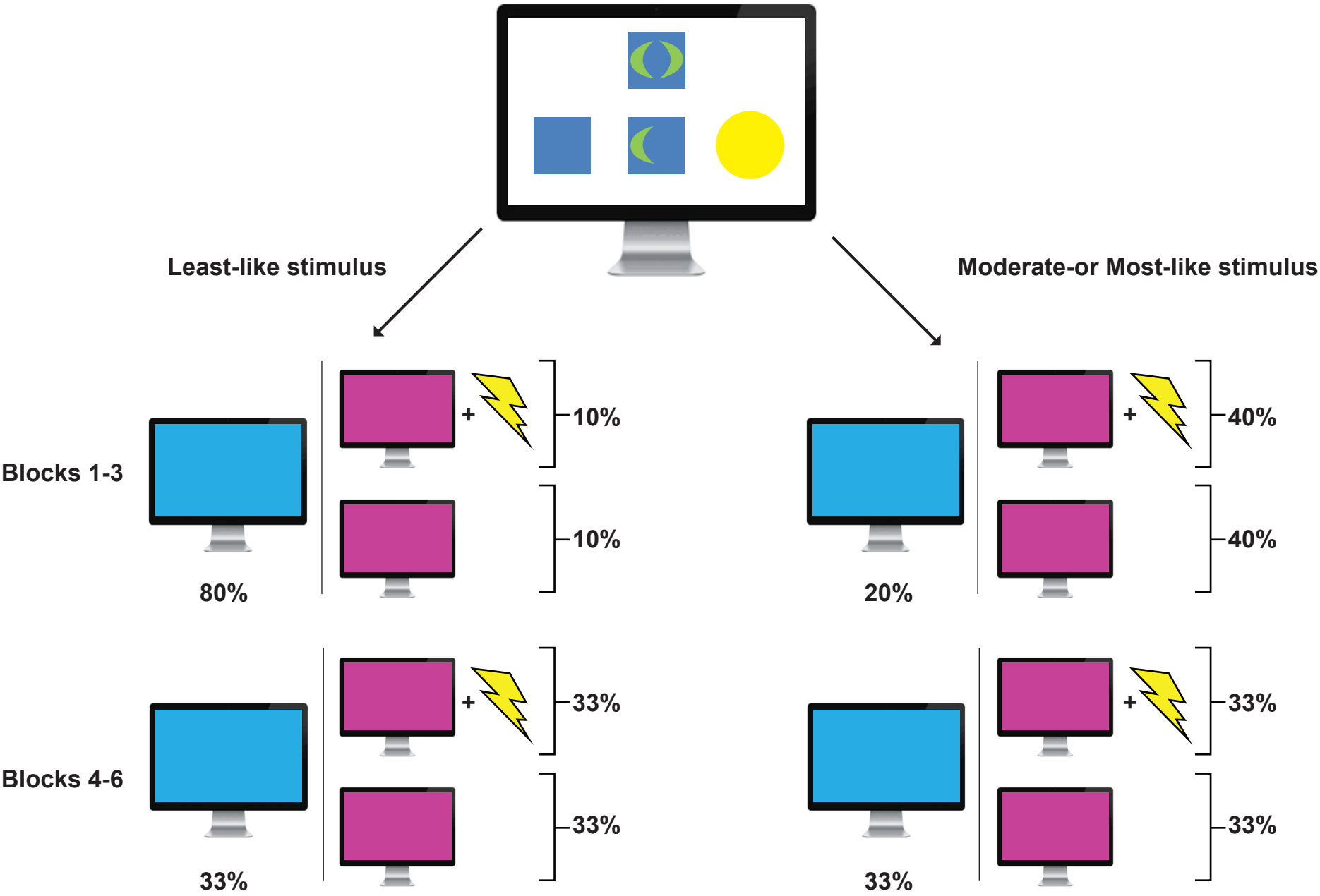
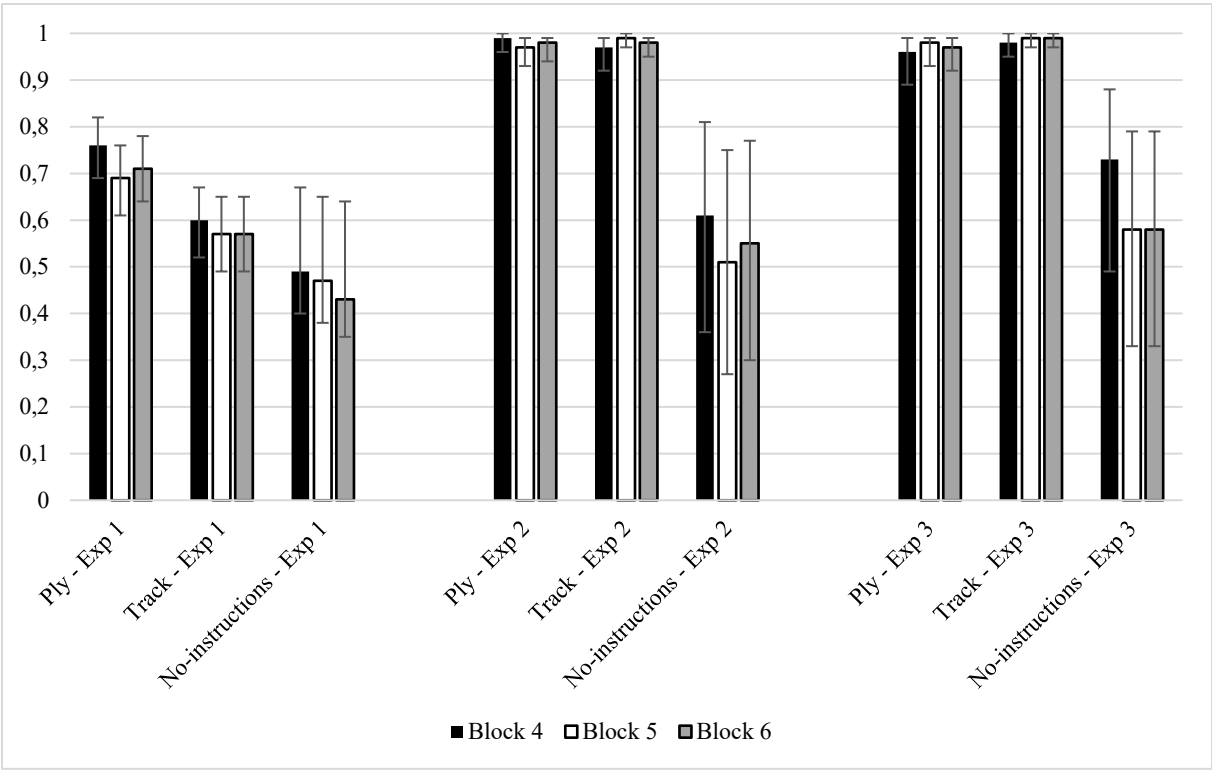


FIGURE 3



SUPPLEMENTARY MATERIAL

Estimated probabilities and 95% confidence intervals of Experiments 1-3

		Block Type					
		Block 4		Block 5		Block 6	
	Instructions Group	$\hat{\pi}$	95 % CI	$\hat{\pi}$	95 % CI	$\hat{\pi}$	95 % CI
Experiment 1	Ply	.76	[.69, .82]	.69	[.61, .76]	.71	[.64, .78]
	Track	.60	[.52, .67]	.57	[.49, .65]	.57	[.49, .65]
	No-instructions	.49	[.40, .67]	.47	[.38, .65]	.43	[.35, .64]
Experiment 2	Ply	.99	[.96, 1.00]	.97	[.93, .99]	.98	[.94, .99]
	Track	.97	[.92, .99]	.99	[.97, 1.00]	.98	[.95, .99]
	No-instructions	.61	[.36, .81]	.51	[.27, .75]	.55	[.30, .77]
Experiment 3	Ply	.96	[.89, .99]	.98	[.93, .99]	.97	[.92, .99]
	Track	.98	[.95, 1.00]	.99	[.97, 1.00]	.99	[.97, 1.00]
	No-instructions	.73	[.49, .88]	.58	[.33, .79]	.58	[.33, .79]

Note. This table contains the estimated probability ($\hat{\pi}$) of selecting the LLCs as a function of Instructions Group (ply, track, and no-instructions group) and Block Type (Blocks 4, 5, and 6), and 95 % confidence intervals (CI) in Experiments 1, 2, and 3.