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Is Pain Contagious? Innocuous Stimulation Can be Transformed Into the Pain Experience by Observational Learning

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Abstract: **Studies indicate that classical and operant conditioning have potential to play a role in the formation of the allodynic effect. Only a few studies have examined the role of observational learning in pain induction. Due to some methodological challenges, evidence that the allodynic effect can be learned through observation is limited. In the present study, healthy participants (n = 88) received 2 series of innocuous electrocutaneous stimuli: at the beginning of the study and after observation of a model who rated all the stimuli as painful. Participants and the model rated all the stimuli alternately (real-time group), or the participant first observed the model and then rated the stimuli, while the model stayed in (post-hoc+ group) or left (post-hoc- group) the laboratory. There was no model in the control group. The study demonstrated that allodynia can be induced by observational learning. Furthermore, this effect was shown to be similar, regardless of whether stimuli were received during the observation of the model and rated immediately afterwards, or when the observation and stimuli reception were time-separated. The mere presence of the model during the stimuli reception also did not affect the magnitude of this effect. This research may contribute to our understanding of the mechanisms of chronic pain development and assist in the development of suitable treatment for it.**

Perspective: ***This article presents study results on the role of observational learning in allodynia induction without tissue injury. The results may contribute to our understanding of the mechanisms of chronic pain development and assist in the development of suitable treatment for it.***

Key words: *Model, modelling, observation, observational learning.*

Allodynia is present when one experiences pain after exposure to an innocuous and often tactile stimulus. Traditionally, allodynia is attributed to peripheral and central sensitization[31] – 2 physiological processes that are associated with tissue damage and ongoing nociception, respectively. Inflammation, vasodilation, axonal reflexes and release of neuropeptides are well-documented processes that sensitize nociceptors and lower the threshold for the activation of nociceptive fibers[31,37] In the case of long-lasting nociception, secondary nociceptors respond to innocuous stimuli, which are typically transmitted through low-threshold myelinated A-beta fibers[37] and the secondary nociceptors become sensitized as a result of neuroplastic alterations in the spinal laminae.

The allodynic effect can also be explained from a psychological perspective, which has so far been greatly underappreciated. Literature on learning mechanisms in pain suggests that pain can be a learned response under certain circumstances. Indeed, some studies on

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classical conditioning on pain suggest that conditioning had potential to amplify pain (hyperalgesia)[3,28] and even induce allodynia.[11] Similarly, a recent systematic review and meta-analysis of studies on operant conditioning suggests that pain can be acquired and maintained even though the noxiousness of stimulation is markedly reduced.[1] However, much less is known about the role of observational learning in allodynia. There is strong evidence that observing others while itching,[38] laughing,[40] or yawning[25,35] affects observers' behavior or even leads to mass psychogenic illness.[9] The idea that pain may be learned from others is well supported on theoretical grounds.[22] Multiple studies have shown that observing other people displaying pain behavior can induce nocebo hyperalgesia[42,45,46] (for a review, see: [4]), reduce pain endurance[44] and even reduce the pain threshold.[13,14,16,17,39] However, there is scant support for the assumption that observational learning can elicit pain.

To the best of our knowledge, only 2 studies have experimentally investigated the role of observational learning in the formation of allodynia.[12,15] In these studies, participants took turns with the model sitting next to them (who was seemingly receiving stimuli at the same time) to assess the emerging electrocutaneous innocuous stimuli in real time. In the experimental groups, the model rated each stimulus in turn as more painful than the participant did. In the control group, the model did not rate the stimuli. This procedure lasted until the participant rated the stimulus as painful or a certain number of trials were completed. In both studies, significantly more participants exceeded the pain threshold in the experimental group than in the control group. Although these and other observational learning studies do not clearly indicate how the time delay between observation and exposure shapes the learned response,[18,33,48] it is reasonable to hypothesize that real-time observation could enhance information retention[8] and thus increase the effect.

The effects of observational learning can be affected by other social phenomena, for example, conformism, and the response bias that occurs in the presence of another person.[2,26] The effect of the mere presence of another person on someone's tendency to conform seems to be strongest in uncertain situations,[24] which is surely the case in experimental studies in which participants are placed in a new situation in which they are evaluated to a certain extent. This uncertainty can be amplified in pain studies in which participants experience unpleasant sensations of a previously unknown intensity. It has been shown that the presence of an experimenter increases the allodynia induced by observational learning.[12] It has not been verified how this effect is affected by the presence of a model; in particular a model who rates the stimuli as painful, as opposed to one who rates them as non-painful or does not rate them at all. It can be hypothesized that the effect would also be significantly larger in this case.

Our primary hypothesis was that allodynia can be elicited by observational learning; our secondary hypotheses were that allodynia induced by observational learning is stronger when the time between observation and stimulation is shorter and that allodynia induced by observational learning is stronger when a pain-maximizing model is present during stimulation of the observer.

Methods

Participants

Eighty-eight volunteers (44 women and 44 men; age: 23.74 $\pm$ 3.24 years) participated in the study. Sample size was calculated a priori by G*Power (G*Power 3.1.9.2 statistical software [20]) using estimated effect size (d_z = 0.78) from a study on the effects of observational learning on pain modulation (hyperalgesia).[42] It was estimated that a minimum sample of 22 participants would be required for each group to reach 80% power in the main (hypothesis 1) t-test comparison between the control group and the observational learning groups (α = 0.05). The inclusion criteria were based on those proposed by Gierthmühlen and collaborators[21]: age between 18 and 35 years; being physically and mentally healthy; not being pregnant; not taking any type of pain medication; not having current ongoing or chronic pain. All the participants were assigned to 1 of the 4 groups (3 experimental and one control) using a block randomization list with a block size of 4, ie, 1:1:1:1 randomization to the real-time or the post-hoc+ or the post-hoc- or the control group, and stratification by sex (male vs female). They were informed that they were participating in a study on human responses to electrical stimuli and that they could withdraw from the study at any time without giving a reason. All participants provided written informed consent to participate in the study. After completion of all the procedures, they were fully debriefed about the real aim of the study, especially those who during the study were erroneously informed that the person they were observing was a naive participant rather than actually a model (see the procedure). Remuneration of 37 PLN (about 10 USD) was provided upon study completion. The Research Ethics Committee of the Institute of Psychology of Jagiellonian University approved the study protocol (KE/04122018).

Stimulation

Innocuous (non-painful) electrocutaneous rectangular pulses, each lasting 200μs, were used for stimulation.[3,5] They were applied to the styloid process of the ulna (non-dominant side) through 2 durable stainless-steel disk electrodes, 8mm in diameter with 30mm spacing. The stimuli were delivered by the Constant Current High Voltage Stimulator (DS7AH, Digitimer, Welwyn Garden City, England). The tailored stimulus intensity was determined in the calibration phase (see below).

Pain Intensity Scale and Questionnaires

Participants rated the experienced pain intensity at the end of each electrocutaneous pulse on an 11-point

Numerical Rating Scale (NRS), ranging from 0 = "no pain" to 10 = "the most pain that is tolerable" (see: [5,7]). The NRS scale was displayed on a black screen just after delivery of each electrocutaneous pulse and remained visible until participants provided their rating. A similar scale, ranging from 0 (no fear of pain) to 10 (maximum imaginable fear) of pain, was used for the measurement of participants' fear of pain upon arrival at the laboratory. After completion of the study, all participants were asked to complete the Need for Closure Scale (NFC[47]; Polish adaptation[30]), which is a measure of need for closure, defined as "a stable dispositional preference for order and predictability, an urgent desire to reach decisions, affective discomfort with ambiguity, and closed-mindedness". This scale consists of 5 subscales (Predictability, Decisiveness, Ambiguity, Closeness, Order). They also completed the Gudjonsson Compliance Scale (GCS[23]; Polish adaptation[49]), which is a measure of compliance, defined by the authors as the tendency to comply with requests in order to obtain short-term instrumental gain. This scale consists of 20 items and 1 dimension.

Design and Procedures

The study consisted of 3 experimental groups, real-time, post-hoc+, post-hoc-, in which there were 4 phases: calibration, pretest, observation and posttest. There was 1 control group, which consisted all of the above phases except observation. In both the pretest and the posttest, all participants received 15 identical innocuous stimuli of an intensity below their pain threshold, which was determined during calibration. In the real-time group, the posttest was combined with an observation, ie, the participant and the model rated the electrical stimuli alternately. In the post-hoc+ and post-hoc- groups, the participants first observed the model and then took part in the posttest. In the post-hoc+ group, the model was present during the posttest; however, in the post-hoc- group, the model had left before the start of the posttest. There was no model in the control group. The study design is shown in Fig 1 and Fig S1.

In the experimental groups (real-time, post-hoc+, post-hoc-), the participant entered the laboratory, in which another person (the model) and the experimenter were already present. The participant was informed that this was another participant who was taking part in the same experimental study but had come to the laboratory a little earlier and had already gone through the first part of the procedure. In fact, the model was a 27-year-old male who had been trained to simulate the experimental procedure and rate the particular electrocutaneous pulse appropriately. This choice of a male model was based on the results of a previous study which showed that a male rather than a female model produced a greater hyperalgesic effect.[42]

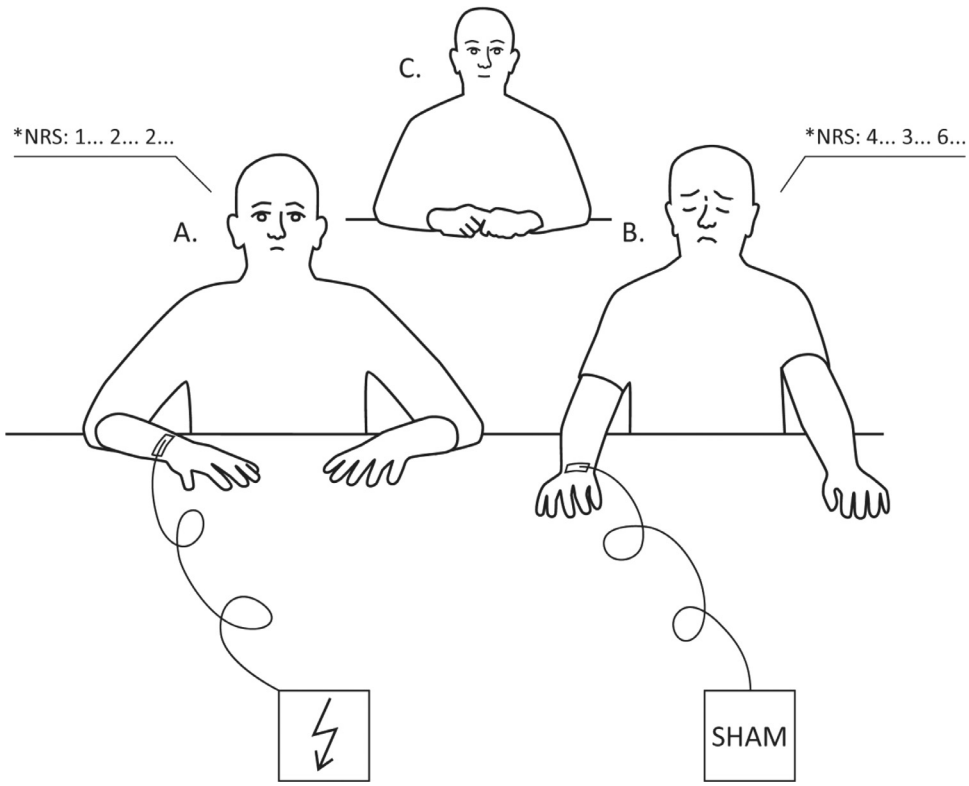

Figure 1. Study design and experimental setup. Four groups were assessed; in 3 of them, different forms of the observational phase between the pretest and the posttest phases were applied. In the real-time observation group, the model (**B**) took turns with the real participant to provide pain ratings (**A**). In the post-hoc+ group, the participant (position C) first watched the model (position B) and later provided their own ratings of innocuous stimulation when the model was present (**C**). In the post-hoc- group, participants watched the model (in position B) first and later provided their own ratings of innocuous stimulation without the model in the room (also position B). In the control group, no observational phase was performed between the pretest and the posttest, thus participant (position A) only provided ratings with a short break in between.

Regardless of the group (experimental only), the model always pretended that he received the painful stimulus by providing ratings ranging from 2 to 6 on the NRS in a predetermined, pseudo-random order (unknown to the real participant and consistent across participants). The participant was also not aware that the model's electrode was not active during the procedure. The participant was informed that for the sake of efficiency and quickness they would be tested together with the model. The model was asked to wait for the next part of the procedure and to take a seat behind the partition wall next to the experimenter where he was out of sight of the participant, unable to see their screen; the participant was asked to take a seat at the computer station and to participate in the first part of the experiment. In all the groups, the experimenter was out of sight of participants during the entire experiment and did not interact with them in any way, except for reading the instructions.

Calibration

In order to determine the intensity of the innocuous stimuli, which were situated between the detection (DT) and pain thresholds (PT), all the participants underwent a calibration phase. A series of electrical pulses of increasing intensity was provided (starting from 0mA, increasing by 1mA, with inter-pulse-interval = 5s) until DT and PT were reached, which stopped the stimuli application. This procedure was carried out twice and the obtained results were averaged. The intensity of the innocuous stimuli was calculated using the following formulas: i. DT + 0.75(PT−DT), ii. DT+0.5(PT-DT) and iii. DT (see *pretest*; formulas no. i and no. ii were 75% and 50% of the distance between the DT and PT, respectively; formula no. iii was equal to DT). The use of 3 gradually decreasing values made it possible to find a non-painful stimulus for each participant that was sufficiently low that the participants would not become sensitized yet sufficiently high that they were able to detect it. These stimulation levels were used in the consecutive phases of the study.

Pretest

Subsequently, participants proceeded to the pretest, in which they received 15 identical innocuous stimuli (20s intervals) of the previously determined intensity (calculated using formula no. 1). Participants were asked to rate the intensity of their pain on the NRS aloud and with the keyboard in order to facilitate the conduct of the experiment. In fact, verbal ratings were introduced to facilitate learning in the observation phase, while electronic ratings were introduced to ensure greater measurement reliability. Those who rated more than 50% (8 or more) of the innocuous stimuli as painful (>0 on the NRS scale) underwent another pretest, but stimulus intensity was reduced (calculated using formula no. 2). Participants who rated the stimuli as painful in the second pretest proceeded to another pretest in which stimulus intensity was calculated using formula no. iii. Participants who rated more than half of the stimuli as painful during the third pretest were excluded from the study and did not take part in the subsequent phases of the study. However, data collection was continued until required sample size of 22 participants per group was reached. This was necessary because such a rating would have meant that the applied stimulus with the lowest detectable intensity (equal to DT) was already painful in the pretest and therefore it would have been impossible to demonstrate the influence of observational learning on the development of pain. The remaining participants proceeded to the next part of the experiment.

Manipulation and Posttest Phases

Real-time group. In the real-time group, the pretest was followed by a break lasting as long as the observation in the post-hoc+ and post-hoc- groups, ie, 5 minutes. The experimenter informed the participant and the model that in order to save time they would proceed to the second part of the experiment simultaneously. The model was asked to take a seat at the PC station next to the participant; the electrode cable, which had already been attached to the model's hand, was connected to the apparatus (Fig 1). The model and the participant were told that they would receive a series of electrical stimuli and would be asked to rate the intensity of the pain they were experiencing on the NRS aloud and with the keyboard. The model and the participant rated the stimuli alternately. A balanced design was used: in 50% of cases, the model started providing pain ratings using the NRS, and then the second rating was obtained from the participant; in the other 50% of cases, the order of the ratings was reversed. During the procedure, the participant received 15 stimuli at an intensity equal to those in the pretest. At the same time, the model pretended to receive a series of 15 stimuli and rated them as moderately painful (2−6 on NRS) according to a predetermined pseudo-random order.

Post-hoc+ group. After the pretest, the experimenter asked the model who was "first in line" to take a seat at the PC station. At the same time, the participant's electrode was disconnected and they were asked to take a seat on a chair that was positioned next to the model in a way that prevented distraction from the pain ratings given by the model (Fig 1). The model pretended to receive a series of 15 electrocutaneous stimuli and rated their intensity on the NRS as moderately painful (2−6 on NRS) in a predetermined pseudo-random order. After completing the observation phase, the model's electrode was disconnected from the apparatus and the model and the participant were asked to switch seats: the participant sat at the PC station and the model sat on a chair next to him. The participant's electrode was connected to the apparatus and they were asked to proceed to the same procedure that they had just observed. In the posttest, the participant received 15 stimuli, applied every 20 seconds at an intensity equal to those in the pretest.

Post-hoc- group. In the post-hoc- group, the procedure was identical to the post-hoc+ group, except that the model's electrode was disconnected from the apparatus immediately after the observation phase; he was then informed that he had completed the entire procedure, then he left the laboratory. At the same time, the participant was asked to take a seat at the PC station and take part in the same procedure that they had just observed. In this group, in the posttest there were only 2 people in the laboratory: the participant and the experimenter.

Control group. With the exception of the absence of the model in the laboratory, the test procedure until the completion of the initial test phases (calibration and pretest) did not differ from that in the experimental groups (real-time, post-hoc+, post-hoc-). After the pretest, there was a short break that lasted as long as the observation in the post-hoc+ and post-hoc- groups (5 minutes). In the posttest, the participant received 15 stimuli, applied every 20 seconds at an intensity equal to that in the pretest.

After completion of the procedure, participants from all groups were asked to complete the questionnaires (GCS and NFC) and answer questions that verified whether they had figured out the aim of the study and whether, in their opinion, the observation and the presence of the other participant was helpful (yes/no) and if it had influenced their pain ratings (yes/no). Several weeks after the entire study had been completed, all participants were debriefed via email.

Statistical Analyses

Data were analyzed and presented using parametric or non-parametric descriptors according to the distribution of the data. If the normality assumption was violated − as indicated by significant Shapiro-Wilk test results ($P < .05$) and high skewness coefficients (> -0.5 or < 0.5) − descriptive statistics were presented as medians and interquartile range; in other instances, parametric tests, means and standard deviations (SDs) were provided. Between-group differences for pain and detection thresholds, age and questionnaire scores were tested using Kruskal-Wallis tests or omnibus ANOVA with group (real-time, post-hoc+, post-hoc- or control) as a between-subject factor.

To address the primary and secondary hypotheses, the Kruskal-Wallis test was used. If a significant main effect was observed, post-hoc Bonferroni-corrected Mann-Whitney U tests were applied. To perform the main analysis, the Kruskal-Wallis test was applied with between-subject factor "group" (real-time, post-hoc+, post-hoc- or control) and the difference in pain ratings (ΔPain) between the pretest and posttest as a dependent variable.

Relative risks (RR) with 95% confidence intervals for pain perception were used as a complementary analysis and calculated using cross tables and the Chi-squared test based on Koopman asymptotic score[29]; the ratios of painful to nonpainful trials in the posttest phase (total of 330 trials per group) were calculated. In principle, the RR of experiencing pain was calculated for the experimental groups in comparison to the control group. Analyses were performed using STATISTICA v.13.0 data analysis software (Statsoft Inc., Tulsa, OK) and GraphPad Prism v.8.0.0 (GraphPad Software, San Diego, CA).

Results

The dataset analyzed during this study is uploaded to the OSF repository per DOI 10.17605/OSF.IO/YGT76 and accessible via the following URL: https://osf.io/ygt76/. Descriptive statistics are presented in Table 1. Participants who rated more than half of the stimuli as painful during the third pretest (n = 9) were excluded from the study and did not take part in the subsequent phases of the study (Table S3). In general, no statistically significant differences were found between the assessed groups in terms of descriptive variables. Namely, participants from different groups had similar detection thresholds ($F_{[3,84]} = 0.94$, $P = .43$, $\eta^2_p = 0.03$), pain thresholds ($F_{[3,84]} = 0.68$, $P = .57$, $\eta^2_p = 0.02$), social compliance ($F_{[3,84]} = 2.05$, $P = .11$, $\eta^2_p = 0.07$), need for closure ($F_{(3,84)} = 1.92$, $P = .13$, $\eta^2_p = 0.06$), level of fear of pain ($H_{[3]} = 1.05$, $P = .79$) and age ($H_{[3]} = 2.23$, $P = .53$).

No differences were found between the medians from the pretest phase among the 4 groups ($H_{[3]} = 1.92$, $P = .59$). Kruskal-Wallis rank tests on ΔPain revealed a statistically significant main effect of "group" ($H_{[3]} = 28.45$, $P < .001$, Fig 2), indicating that the increase

Table 1. Mean (or Medians) and Standard Deviations (Interquartile Range) for Measured Variables

Variable	Group			
	Real-Time (n=22)	Post-Hoc+ (n=22)	Post-Hoc- (n=22)	Control (n=22)
Age (y)	23.5 (2.79)	24.09 (3.98)	22.91 (2.64)	24.45 (3.40)
Detection threshold (mA)	6.07 (2.60)	5.43 (1.76)	5.59 (1.82)	5.11 (1.27)
Pain threshold (mA)	15.66 (7.34)	19 (8.50)	17.59 (7.45)	16.14 (10.76)
Pretest* (0−10, NRS)	0.1 (0.00−0.33)	0.03 (0.00−0.27)	0 (0.00−0.20)	0.13 (0.00−0.20)
Posttest* (0−10, NRS)	0.9 (0.53−1.73)	0.77 (0.33−1.40)	0.43 (0.20−0.93)	0.1 (0.00−0.27)
Fear of pain (0−10, NRS)	1.29 (1.52)	1.41 (1.37)	1.14 (1.58)	1.27 (1.16)
GCS	9.00 (3.06)	7.27 (2.66)	7.14 (2.68)	7.5 (2.89)
NFC	54.14 (6.71)	50.23 (5.72)	53.27 (5.01)	50.73 (7.94)

Abbreviation: GCS, Gudjonsson Compliance Scale; NFC, Need for Closure Scale.
*Medians and interquartile range.

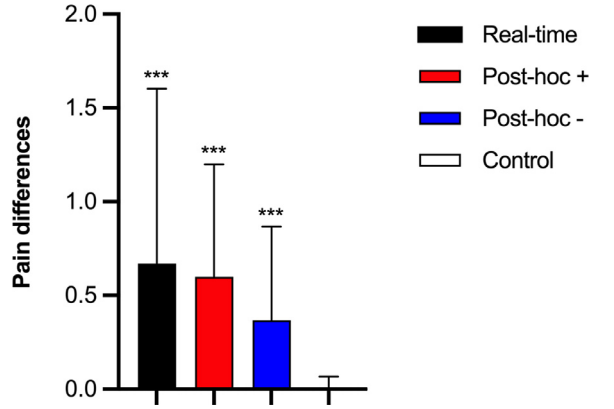

Figure 2. Median differences in pain perception in the experimental groups. Bars present the magnitude of the allodynic effect, ie, median values calculated for the differences in pain between the posttest and the pretest. Higher bars indicate greater effect. $^{***}P < .001$.

in pain during the posttest phase varied between the groups. Post-hoc Bonferroni-corrected Mann-Whitney U tests revealed significant differences in ΔPain between the real-time group and the control group (Z = 4.64, $P < .001$); between the post-hoc+ group and the control group (Z = 4.13, $P < .001$); and between the post-hoc- group and the control group (Z = 3.81, $P < .01$). These results indicate that the allodynic effect was found in all 3 experimental groups (Fig 2 and 3). An analogous pattern was found in the results when analyzing the data from the posttest phase only ($H_{[3]} = 21.61$, $P < .001$). Namely, post-hoc Bonferroni-corrected Mann-Whitney U tests revealed significant differences between the real-time group and the control group (Z = 3.99, $P < .001$); between the post-hoc+ group and the control group (Z = 3.65, $P < .001$); and between the post-hoc- group and the control group (Z = 3.08, $P < .01$).

Relative risk analysis revealed a significantly higher risk of having a painful trial during/after the observational phase (Table 2): participants from the real-time group had 3.83 higher RR of experiencing pain than those in the control group (95% CI: from 3.01 to 4.91, $P < .001$). Similarly, RR of painful events was 3.28 in the post-hoc+ group (95% CI: from 2.56 to 4.23, $P < .001$) and 2.93 in the post-hoc- group (95% CI: from 2.28 to 3.80, $P < .001$). Interestingly, a 1.31 higher risk of having pain was observed in the real-time group compared to the post-hoc- group. The risk of experiencing pain in the pretest was not significant in any experimental group compared to the control group.

Exploratory correlational analyses only showed negative correlations ($r_s = -0.43$, $r_s = -0.44$) between the allodynic effect (ΔPain) and GCS (post-hoc-) and FOP (post-hoc+). However, neither were significant after the Bonferroni correction, thus they were treated as such (Table S1). Manipulation check demonstrated that the blinding procedure was quite effective, since only 4 people figured out the real aim of the study (2 in the real-time group, 1 in the post-hoc+ group and 1 in the post-hoc- group). Frequency of responses (yes, no) are presented in Table S2. Exclusion of 4 participants who figured out the real aim of the study, did not change the results of the study.

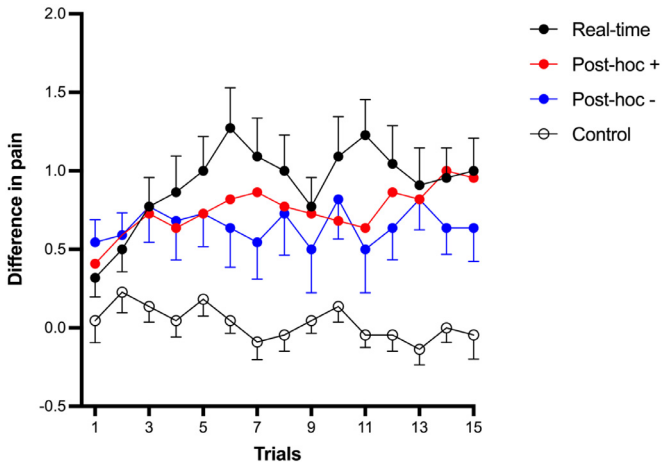

Figure 3. Differences in pain between the posttest and the pretest in all trials. Positive values indicate higher pain in the posttest. Error bars for the post-hoc+ group are not shown for clarity. Negative values in the control group indicate that some of the posttest trials in this group were assessed as non-painful compared to the pretest. Data are presented as means and SDs.

Discussion

Research indicates that not only biological factors but also the environment can modify how humans experience pain.[34] Our study has shown that pain can, in some way, be contagious: other people's behaviors can influence reports that reflect the perception of innocuous stimuli. Specifically, we found that observation of people reporting pain could evoke the allodynic effect without any tissue damage and/or the ongoing nociception that is typical of injury. As an effect of observation, participants in all the experimental groups were significantly more likely to rate stimuli as painful in the posttest compared to the pretest phase, even though in both phases the stimuli were invariably innocuous (equal to or barely above DT). This effect did not occur in the control group, which was not exposed to any observation. Interestingly, for some participants in the control group, we observed even lower pain scores in the posttest than in the pretest phase; this indicates that the observation in experimental groups not only led to allodynia but also prevented habituation to repeated electrocutaneous stimuli.

The main goal of our experiment was to test whether observational learning alone, without additional verbal and non-verbal suggestions, could elicit allodynia, ie, the onset of pain evoked by innocuous stimuli. Previous studies have suggested that observational learning may be the mechanism responsible for the generation of pain;[12,15] however, they did not conclusively determine whether allodynia could be triggered by observational learning. To reduce the influence of suggestion, no explicit instructions about the aim of the experiment or the stimulus intensity were given in our study. Increased

Table 2. Results of the relative risks analysis

Ratio	*RR*	*95% CI*	*p*	*Z*
Real-time to Control	3.83	3.01 to 4.91	<0.001	12.92
Post-hoc+ to Control	3.28	2.56 to 4.23	<0.001	10.61
Post-hoc- to Control	2.93	2.28 to 3.80	<0.001	9.17
Real-time to Post-hoc+	1.17	1.04 to 1.32	=0.01*	2.57
Real-time to Post-hoc-	1.31	1.15 to 1.49	<0.001	4.12
Post-hoc+ to Post-hoc-	1.12	0.97 to 1.29	=0.12	1.56

Table includes means and standard deviations or medians and interquartile range.
*Nonsignificant after Bonferroni correction.

reliability of the experimental manipulation was provided by including the pretest phase, whose purpose was to determine how participants assess stimuli before the observation. We found that observational learning alone is effective and sufficient to induce pain by stimuli previously assessed as non-painful.

Our study provides strong support for the assumption that pain can be induced by observational learning rather than conformism or the response bias that occurs in the presence of another person. This is particularly relevant for the first group (real-time), in which the participant and the model rated the stimuli alternately and there was a greater risk that the participant would just repeat the model's responses instead of providing valid ratings representing pain. Due to the introduction of 2 groups in which participants assessed stimuli with (post-hoc+) or without (post-hoc-) the presence of the model, it was demonstrated that the mere presence of the model during the posttest did not affect the pain ratings. Furthermore, the present study showed that there was no relationship between compliance (as measured by the GCS scale) and the effectiveness of observational learning. The data obtained is in line with the results of a previous study which found no relationship between compliance and the magnitude of the placebo effect induced by observational learning.[6]

The present study is the first to examine whether the effect of observation is influenced by the time-separation between the observation of the model receiving electrocutaneous stimuli and the reception of the stimuli by the observer. This was possible thanks to the involvement of 2 testing groups: in one, participants rated the stimuli alternately with the model (real-time group); in the other, participants first observed the model and then rated the stimuli themselves (post-hoc+ and post-hoc- groups). The study indicated that observational learning induced allodynia of similar magnitude, regardless of whether stimuli were received during the observation of the model and assessed immediately afterwards, or when the observation and stimuli reception were time-separated.

Some strengths of the study should be highlighted. First, the sample size in the current experiment was 4 times larger in comparison to the earlier reports (88 vs 20/48 participants).[12,15] Second, unlike in the previous studies,[12,15] in which the same detection stimulus was used for each participant, we performed a calibration and a pretest in order to prevent sensitization and ensure that the stimuli were not painful for some people from the very beginning. The pretest was also needed to conduct the within-group comparisons. Third, the groups were balanced in terms of gender. In most previous studies concerning the effects of observational learning on pain, only males[12,15] or only females were involved.[10,27,43]

Some limitations of the current study should be also acknowledged. First, acute pain induced by electrocutaneous stimulation was studied, so our results may not be directly translated to clinical pain.[36] Second, the study was conducted in a controlled and safe laboratory situation, which is vastly different from a clinical situation in which the patient cannot predict the subsequent development of pain and its associated health effects. Third, the most sensitive participants (those in whom the calibration was not successful) were excluded from the study. This was methodologically necessary because, due to the inability to determine a non-painful stimulus, it was impossible to demonstrate a pain-inducing effect. Fourth, self-reported pain ratings were our only pain measures. Although psychophysiological or other assessments could provide more information on behavioral responses to stimulation, the self-report lines up with the definition of pain and is the gold-standard approach for assessing pain in verbal humans. Fifth, the participants were aged 18 to 35 years because there are age-related differences in pain perception.[32] Thus, if the results were to be generalized to other age groups, it should be done with great caution. Lastly, we did not measure the physiological correlates of sensitization, but its occurrence is unlikely given the habituation trend in the control group as well as the inter-stimulus interval, which was 10 times longer than it is in a typical procedure to evoke temporal summation.[41]

The current findings have important clinical implications. It seems that apart from purely biological processes, such as primary and secondary hyperalgesia, learning mechanisms such as learning through observation may contribute to people experiencing pain when exposed to innocuous events. The effect of pain contagion may be seen in many contexts, but the medical context is most crucial: seeing other people who have just undergone surgery or medical intervention exhibit pain behaviors could not only increase the level of discomfort during an intervention but may also negatively influence the therapeutic outcome. This may imply the need to reorganize existing places where, due to the specific

nature of medical interventions, acute pain is unavoidable (ie, treatment rooms or outpatient clinics) so that patients at risk of chronic pain (eg, post-surgery patients) are not in the presence of other patients who exhibit pain behaviors. The role of observational learning may be more pronounced in clinical than in experimental settings due to the communication prerogative and the expectation of care involved in pain reports. The effect of pain contagion also occurs commonly in daily life: mere observation of others' pain[4,19] or other symptoms, eg, itching,[38] dizziness and nausea (for review see: [9]), eg, on social media or in a public place, can trigger similar experiences in observers. Therefore, the introduction of educational programs which would explain the process of pain development could be valuable. It is likely that awareness of the mechanisms responsible for pain learning would reduce the strength of this effect; however, confirmation of this thesis requires further experimental studies.

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Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jpain.2022.07.015.

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