# *Influence of experimental pain on the perception of action capabilities and performance of a maximal single leg hop*

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**Abstract**

Changes in an individual's state, e.g. anxiety/chronic pain, can modify the perception of action capabilities and physical task requirements. In parallel, considerable literature supports altered motor performance during both acute and chronic pain. This study aimed to determine the effect of experimental pain on perception of action capabilities and performance of a dynamic motor task. Performance estimates and actual performance of maximal single leg hops were recorded for both legs in 13 healthy participants before, during and after an episode of acute pain induced by a single bolus injection of hypertonic saline into *vastus medialis* of one leg, with the side counterbalanced between participants. Both estimation of performance and actual performance were smaller during pain, than before and after pain. This decrease in estimation and performance during pain was apparent for hops using either leg, but was greater for the painful than control leg. Participants accurately estimated their performance in all conditions for both legs. The results provide evidence that healthy participants have the ability to update action-scaled relationship between perception and ability (affordance) during acute pain. This study provides a first step towards understanding the potential for pain to modify the relationship between motor performance and perceived abilities.

**Perspective**: This experiment aimed determining whether acute muscle pain influences the relationship between perceived ability and actual performance. Individuals effectively updated their action-scaled affordances during acute pain. These disturbances could be relevant during clinical pain assessment, with the potential to be a biomarker of transition from acute to chronic pain state.

Key words: performance, pain, hypertonic saline, affordance, hop

## Introduction

The adaptation required to achieve a given behavior within constantly changing environmental constraints, is an integral part of human daily life. The task-specific fit between an individual's perception of the environment, and what they can achieve within this environment, is knows as an "affordance" [5]. For instance, the affordance "stair-climbability" is related to both the characteristics of the stair (e.g. riser height) and the physical capability of the individual [35]. Numerous studies demonstrate healthy humans accurately perceive their physical capabilities for tasks such as reaching [21], grasping [22], jumping [29], and walking through apertures [10]. However affordances are compromised during periods of altered psychological state. For example, Graydon *et al.* [8] reported that anxious participants underestimate their reaching, grasping and passing ability compared to non-anxious participants, and argued that these behaviours reflect a protective mechanism.

Considerable literature supports altered motor performance during both acute experimental pain (e.g. reduced force-generating capacity in most [6,7,14,31] but not all studies [46], and altered kinetics around the joint related to the painful muscle [1,12,13,14,15,24]) and chronic pain (e.g. reduced force-generating capacity [7,19,20], altered kinetics [6], and reduced time to task failure during submaximal tasks [25]). Altered motor performance during pain may serve to reduce stress on painful tissue and/or avoid further pain [21,34]. It is unclear, if the individual in pain accurately perceives this change in performance-ability during pain. If not, the individual with pain could overestimate their physical capabilities (i.e. the function is reduced but belief in performance-ability is not altered) and thus be more likely to overuse the painful part with potential for both short-term (acute injury) and long-term consequences. Alternatively, they may underestimate their physical abilities, or overestimate the physical cost of performing a moment task (e.g., walking distance is overestimated in people with chronic pain, [37]) and thus reduce movement/physical activity (as observed in older adults with chronic pain, [9]), which may be harmful to general health in the long term.

This study used an acute pain model to investigate the effect of pain on affordances in healthy participants to provide a first and critical step towards understanding the unique potential for pain to modify the relationship between motor performance and perceived abilities. We hypothesised that, consistent with other observations, maximal performance of the motor task would reduce during acute pain, and that this reduction in maximal performance would be associated with reduction of the estimated ability to perform the task. Finally, as theories of the adaptation to acute pain predict changes in motor performance in and around the painful region, with little evidence (or consideration) of more generalised effects on motor performance including movement of body regions other than the painful part, we hypothesized that changes in motor performance, if present, would be confined to the painful part. To test these hypotheses we investigated the effect of acute experimental leg pain in healthy participants, on both perception of action capabilities and performance of single leg hops.

## Method

### *Participants*

Thirteen healthy males volunteered to participate the study (28.7 ± 5.5 years; 179.2 ± 5.3 cm; 73.5 ± 7.7 kg. All participants indicated a preference to lead with the left leg when high jumping. Exclusion criteria were visual or physical impairments, psychiatric or neurologic disorders, or any long-term medications. Participants were informed of the experimental tasks before providing written consent. The experimental design of the study was approved by the Ethical Committee of Nantes Ouest IV (reference: n° CPP-MIP-002) and was conducted in accordance with the Declaration of Helsinki (last modified in 2004).

*Materials and apparatus*

A rigid blue carpet (2 cm thick; 7 m long, 1 m width) was laid on floor, with white scotch-tape placed across the width of the carpet to indicate the start position. A scotch-tape mid line (perpendicular to the start line, in the middle of the carpet) extended 5 m from the start position. Participants were asked to focus on and aim for the mid line when estimating their hop performance and when performing the single leg hop task. No other visual marks were available.

To measure the participant's judgment of their perceived ability they were asked to estimate the distance they predicted they would be able to hop by indicating "stop" as the experimenter moved a stick (placed transversely across the width of the carpet, and with a 120 cm handle) gradually (~ 20 cm/s) away from the starting line. At this point the participants gave instructions ("further" or "closer") to the experimenter to make minor adjustments to the stick's position in order to estimate the maximal distance they predicted they could achieve with a maximal single leg hop, as accurately as possible. A wooden graduated ruler (3 m long, not visible to the participant) that lay on the edge of the carpet, was used by a second investigator to measure the indicated distance.

For the single leg hop performance, hop distance was determined using a digital camera (Casio Exilim EX-ZR100, Japan; sampling frequency of 120 Hz) that was aligned with the estimated hop performance, but was not in visual range of the participant. To overcome the image parallax a calibration of the camera image was performed before and after the experiment.

*Procedure*

Participants first performed 5 minutes of warm-up cycling on a cycle ergometer (power output=100 Watts). The perception and performance tasks were then explained to the participants and they performed three practice hops on each leg.

A series of performance estimates and actual performance was recorded before pain, during pain, and after pain had ceased (approximately 5 minutes after completion of the 'pain' trial). Participants performed six performance-estimates (three per leg, in counterbalanced order between participants) of their own maximal single leg hop performance during the pre-pain and post-pain conditions, and four performance-estimates (two per leg) during pain. The reduced number during pain is based on time restrictions of this pain model. Maximal leg performance was defined as the maximal distance at which one could hop from one leg (without using their opposite leg for stability before the jump), and land on that same leg, without losing balance [2,26,30]. Participants were instructed to stand on the required leg, with the lead toe behind the starting line, and to make their judgment by considering their action capabilities at the present instant. Between each performance-estimate, participants closed their eyes and turned away from the carpet, while the experimenter returned to the starting position. After providing the performance-estimates, participants were instructed to perform a series of six single leg hop tests (three trials per leg, in counterbalanced order between participants) during the pre-pain and post-pain conditions, and two single leg hop tests (one per leg) during pain. Participants stood in the same starting position before each hop, and at least 40 seconds of recovery was provided between 2 consecutive trials of the same leg to minimize fatigue (typically less than 30 seconds is sufficient, [30]).

*Experimental Pain*

Acute experimental muscle pain was induced by a single bolus injection of hypertonic saline (1mL, 5% NaCl, 25mm x 25G needle) into the distal portion of *Vastus medialis* (of the dominant or non-dominant leg, with pain side counterbalanced between participants). Pain level was reported on an 11 point numerical rating scale (NRS), where 0 = no pain, and 10 = most extreme pain imaginable. Once pain level was reported as at least 2/10, participants were instructed to move to the 'start-line', for the performance estimates to begin. Pain level was reported immediately before and following each performance estimate and hop, during the pain condition. The average of these two pain estimates were used for analysis. After completion of the pain trial, participants drew the region of pain experienced, on their own leg, and a photograph was taken (Fig 1).

*Data analysis*

All data were normally distributed and thus values are reported as mean ± standard deviation. Statistics were performed on the *average* and the *maximum*, performance estimates and actual performance for each condition. The results were the same, irrespective of which measure we used, and therefore only maximum data (i.e., one value per condition) are discussed.

First, reported pain intensity was compared, using a 2-way ANOVA with repeated measures 2 (Measure – estimates and performance) × 2 (Leg – control and painful leg).

For maximum estimate and performance, a 3-way ANOVA with repeated measures (Condition – pre-pain, pain and post-pain) × 2 (Measure – estimates and performance) × 2 (Leg – control and painful leg) was first performed. Tukey HSD comparisons were used for post-hoc tests following significant main effects. Significance was set at $p < 0.05$.

## Results

*Pain intensity*

The reported pain intensity during the performance estimates (5.3±0.5 /10) was slightly higher than that reported immediately following the actual hop performance (4.7±0.4) (main effect Measure: $F(1, 12) = 8.34$, $p < 0.02$). However, there was no difference in the intensity of pain reported “between legs”, i.e. reported pain intensity was similar when participants stood on their test (painful) or control (non-painful) leg and estimated their maximal hop, and when they performed the hop on the painful and non-painful leg (main effect of leg: $F(1, 12) = 0.187$, $p = 0.67$).

*Performance estimates and actual performance*

Before pain was induced, participants estimated that they could perform a single leg hop of 194.1 ± 28.6 cm, and their maximum hop performance was 201.6 ± 24.2 cm Participants accurately estimated their performance in all conditions (pre-pain, pain and post-pain) for both the painful and non-painful legs (i.e. no significant main effect of measure (performance estimate vs. actual performance: $F(1, 12) = 0.912$, $p = 0.36$), or significant interaction considering this factor (all $F$s < 1.63, $p > 0.22$).

Both estimation of performance and actual performance were reduced during acute pain (main effect condition: $F(2, 24) = 8.61$, $p < 0.01$; post hoc pain vs. pre-pain -

8.1 cm, i.e., -4.1 %; $p$ <0.02; pain vs. post-pain -10.2 cm, i.e., -5.1 %; $p$ <0.01). There was no difference between pre- and post-pain measures ($p$ = .71) (Fig 2). The decrease in both estimation and performance during pain was apparent for hops using either leg, but was greater for the painful leg than the control leg (-10.8 cm vs. -5.5 cm for painful and control leg, interaction condition × leg: $F(2, 24) = 3.76$, $p$ <0.01; post hoc: $p < 0.01$) (Fig 3).

**Discussion**

The aim of the present study was to determine if acute pain alters the relationship between perceived ability and actual performance in healthy participants. In support of our first hypothesis, the performance of the single leg hop was reduced during acute pain. In support of our second hypothesis, there was no change in the relationship between perceived ability and actual performance such that participant's perception of their ability to hop was adjusted in a manner that was concordant with their change in performance. As both the actual performance and estimation of performance were reduced in a similar manner this indicates the task-specific affordance was unchanged during acute pain. This means either that the healthy individuals accurately estimated the reduction in their ability to perform the task during acute pain or, they adjusted their actual performance on the basis of an estimated/expected reduction in ability. This study cannot distinguish which of these alternatives explains the results. In contrast to our third hypothesis, there was also a reduction in both the task performance and estimation of performance when the task was performed with the non-painful leg. However, this reduction was smaller than that observed for the painful side. This provides evidence of a more subtle generalized change in motor performance and perception of motor performance that do not necessarily relate to the immediate location of pain, but with lesser magnitude.

Various studies have shown that task performance is altered during experimental pain (e.g. reduced torque during maximal voluntary contractions [6,7,14,32] and altered kinetics during movement tasks [1,11,12,13,15,24]). This reduction in maximal performance is thought to relate to either a reduction in total motor drive (e.g. generalised inhibition of the muscles in or near the painful site (see review, [23]), which is not supported by all studies [19], or a change in the manner in which the force is generated. With respect to the latter, reorganisation of the control of movement such as a redistribution of muscle activity within and between the muscles used to perform the task has been hypothesised (see review, [16]). This is the first study to test, and demonstrate reduced maximal performance in a dynamic, multi-joint task (i.e. distance of a single leg hop) during acute pain.

Although the reduction in performance might be explained by an actual reduction in maximal ability to perform the task (e.g. inability to exert maximal effort), the maximal performance might also be reduced as a protective mechanism, whereby an individual in pain moderates their performance (and estimation of performance ability) to increase the “safety margin” for the task to expose their system to less risk. This is supported in part by the smaller, but significant, reduction in performance and performance estimation in the non-painful leg. In that case the individual may still reduce the maximal performance to increase the safety margin, as a contribution from the painful leg is required to stabilise the individual if they were to lose balance with hopping. Reduction of the actual performance (use of a more conservative strategy, that is less than the true maximum potential) would lessen the chance of loss of balance, and thus reduce the possibility to need to use the painful region (for balance).

The second key finding is that participants accurately predicted their decrease in performance ability during acute pain (or they performed in a way that they had predicted). This provides evidence that the presence of experimental pain did not alter the critical cognitive updating process, and that an adequate protective mechanism was maintained to meet the painful context. This is in line with our understanding that action-scaled affordances are dynamic, and can evolve both rapidly (reviewed in [4]), and over longer time scales (e.g. in people with chronic pain [37]) and in older adults [10,27]. For example, people with chronic low back estimated a larger distance to walk to a target than pain-free controls, which is argued to be associated with the perception of greater effort required to achieve this distance. This supports the idea that individuals perceive the environment in terms of the costs of acting within it. Thus, patients who experienced chronic pain overestimated the walking distance, as an indication of embodied pain sensation cost [37]. Overall these results highlight an updating action-scaled affordances process during painful episodes. Further work is necessary to determine the effectiveness of this process in different clinical populations.

Finally, contrary to our expectations, the present study results highlight an influence of pain on both perceived action capabilities and performance that is not specific to the action being performed local to the site of pain. We observed a decrease in estimation and performance of the maximal hop, for both the painful and the non-painful leg (albeit greater reductions on the painful side), during pain (Fig 2). It is possible that the presence of pain in an unrelated region diverts attention from the experimental task, and that this reduction in attention to the task may compromise performance [17]. This has been shown for other distractors, not related to pain. For example, distraction by points of light while climbing on a high traverse reduces both perceived and actual performance [28]. It is also possible that the reduced performance in the non-painful leg is related to a protective mechanism (as discussed above). Finally, generalized effects of altered motor ability in one region may affect performance ability in an unrelated muscle. For example and handgrip fatiguing task, has been shown to alter maximal force generating capacity of plantarflexor muscles [18]. Again, we can argue from these unexpected findings that an acute muscle pain (induced in healthy young participants) does not alter the necessary updating process of their motor capabilities, as both performance ability and perceived ability changed in parallel. Further research is required to test this assumption of shared processes for top-down control of (selecting and recalibrating) affordances and motor adaptation to pain [33].

**Conclusion and clinical significance**

This experiment was conducted to determine whether acute muscle pain influences the relationship between perceived ability and actual performance in healthy participants. We provide evidence that healthy individuals effectively update their action-scaled affordances during acute pain, i.e. the short-term reduction in motor performance during acute experimental pain is associated with a recalibration of movement capabilities. Evidence that the reduced performance (and perception of performance ability) occurs both local and contralateral to the painful site provides some evidence that the reduction in performance is not necessarily related to reduced motor potential, but rather increasing the “safety margin” of the task. The potential for an individual in pain to modify their performance ability to increase a “safety margin” is particularly relevant when measures such as the single leg hop test are used in clinical pain studies to determine progression and/or recovery from lower limb pain conditions [36]. This is because, independent of any functional alteration present in clinical populations, the acute nociceptive stimulation (in combination with the individuals cognitive processes associated with this experience) is sufficient to induce a reduction in task performance i.e. reduced single leg hop may be associated with current pain (and potentially pain related cognitions) rather than actual functional capability.

This study provides a first step towards understanding the potential for pain to modify the relationship between motor performance and perceived abilities. It is now critical to determine if action-scaled affordances process are updated in a similar way in more diverse samples of people with differing pain cognitions, and in people living with clinical pain. We argue that it is possible that affordance disturbances could be relevant during clinical pain assessment, with the potential for this measure to be an early biomarker of the transition from an acute to chronic pain state.

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**Figure Captions**

**Fig. 1:** The location of painful injection (arrow) and area of pain (open grey circles) reported by participants on completion of pain trials are shown. VL, *vastus lateralis*; VM, *vastus medialis*.

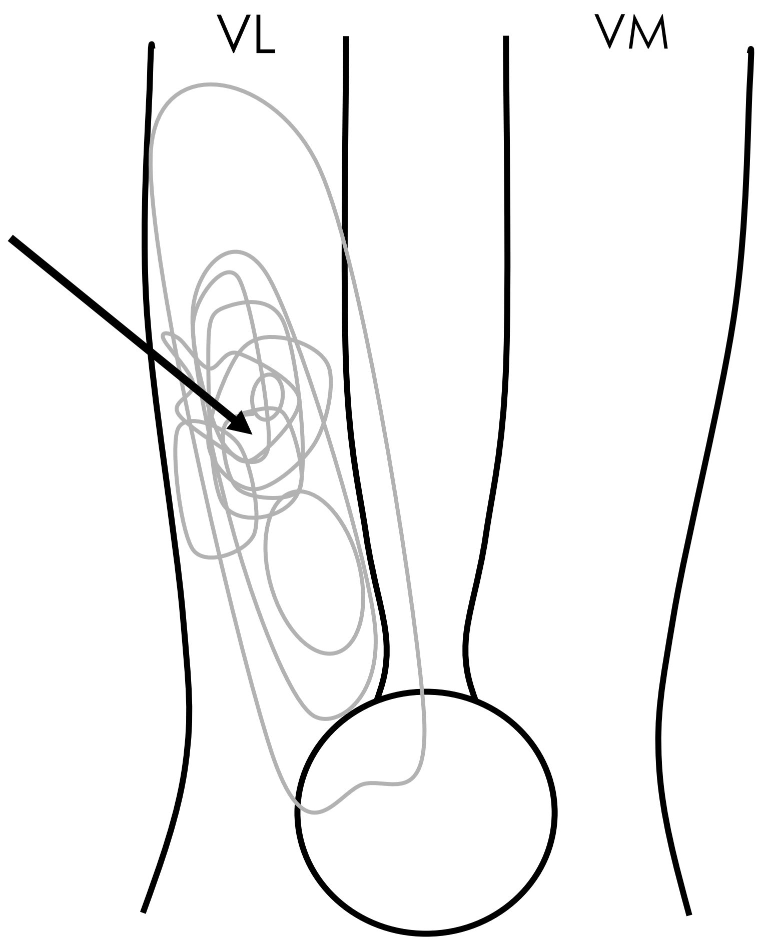

**Fig. 2:** Both the estimation of performance ability (grey) and actual performance (black) were reduced during acute pain compared to the pre-pain and post-pain conditions.

*Error bars correspond to the standard deviation. Significant differences at * $p < 0.05$.*

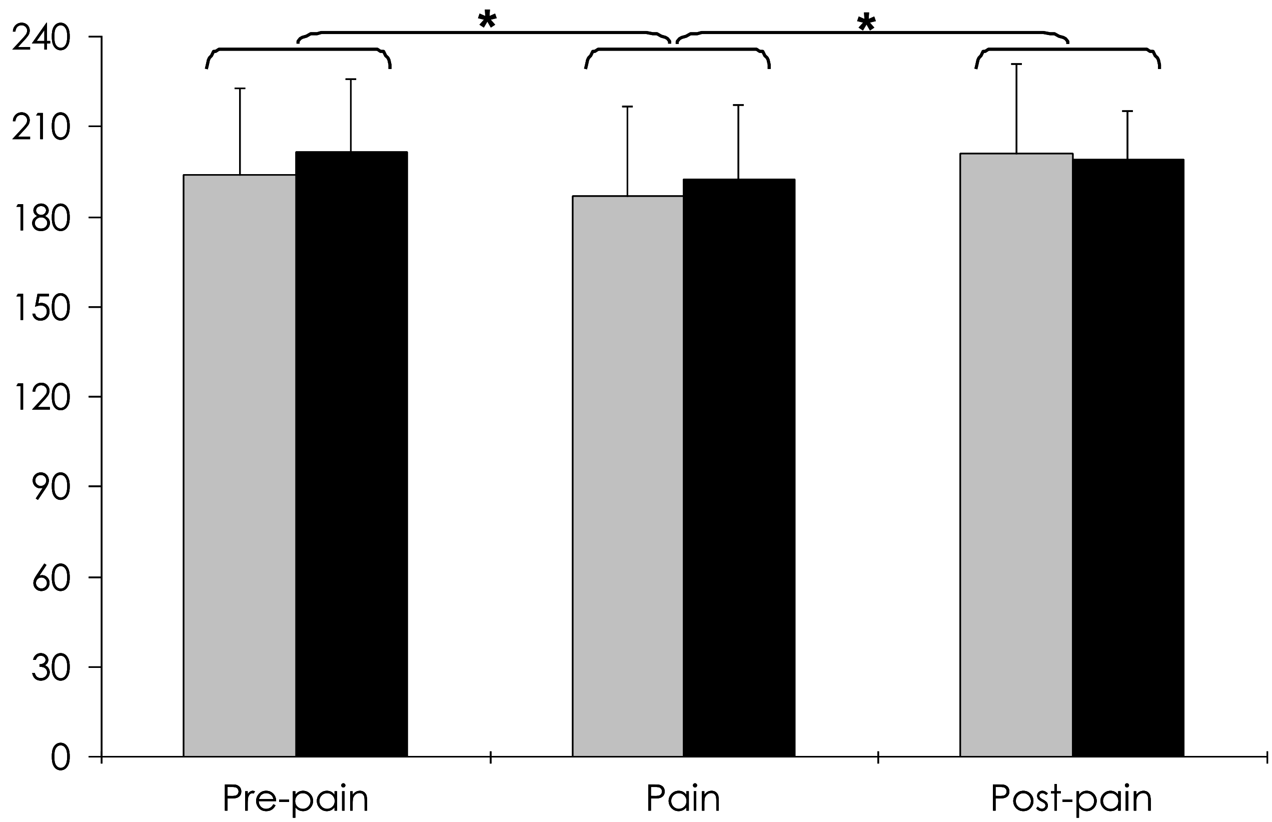

**Fig. 3:** Performance estimates and actual performance were similar, and are therefore combined to demonstrate the reduction in these measures during the painful condition. This reduction was observed for both the legs, but was greater in the painful (black) than the non-painful (grey) leg.

*Error bars correspond to the standard deviation. Significant differences at * p < 0.05; *** p <0 .001.*