

Virtual Touch and the Human Social World

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Highlights [85 char]

- Haptic stimulation of endorphin acts to bond relationships in primates and humans
- Humans have found ways to trigger the endorphin system virtually without touch
- Virtual 'touch' allows humans to 'groom' at a distance with more individuals

Abstract

Touch forms a central component of social bonding, both in primates and in humans, via the brain's endorphin system. In primates, this involves social grooming, acting via the CT neuron system. Although humans still use soft touch for bonding relationships, they have had
5 to find ways of triggering the endorphin system without the need for physical touch in order to be able to increase the size of their social groups beyond the size of those characteristic of monkeys and apes. These behaviours include laughter, singing, dancing, the rituals of religion, feasting and emotional storytelling, and act functionally as a form of 'virtual touch'.
I summarise recent behavioural, neurobiological and genetic evidence demonstrating that
10 these behaviours both enhance bonding and act through the endorphin system.

Key words: Touch, endorphins, grooming-at-a-distance, laughter, singing, dancing

Introduction

Primates are intensely social animals, with a form of bonded sociality that is all but unique among the birds and mammals. These bonded relationships are mediated by social grooming, acting through the brain's endorphin system [1-2]. Although humans lost most of their body hair around 2 million years ago, this bonding mechanism is still central to our social bonding, albeit now adapted in the form of stroking, hugging and caressing.

Nummenmaa et al. [3] confirmed, using PET neuroimaging, that stroking by a romantic partner dramatically elevates endorphin upregulation in humans. Endorphin uptake was present throughout the brain except for the primary visual cortex (occipital lobe) and most of the brainstem and midbrain. The sweeping motions of the hands during grooming trigger the low-threshold c-fibre mechanoreceptors (CLTM) in the skin at the base of the hairs [4], resulting in a signal via the slow CT neuron system directly to the posterior insular [5], from where it seemingly activates the endorphin system. The resulting opiatelike response of heightened analgesia, warmth, calmness, relaxation and trust induces a sense of emotional closeness with the individual involved that gives rise to bonding [6-7].

As a bonding mechanism, social grooming suffers from two major disadvantages. First, the very intimacy of touch means that you can only groom (or, in humans, caress) one individual at a time (in part because focussed attention seems to be important). Second, the strength of a bond depends directly on the time invested in it [8]. Constraints on the availability of social time sets a limit at around 50 on the size of social group that can be bonded by social grooming, and no nonhuman primate has mean social group size larger than this.

Over the last ~2 million years, humans have undergone a dramatically accelerated evolution away from the ancestral great ape lineage, mainly reflected in the evolution of much larger social groups, culminating in the groups of 150 that now characterise modern

humans [9]. Since the limit on group size in nonhuman primates seems to be set by the constraints on the number of individuals that can be groomed at the same time, humans needed to find new ways of triggering the endorphin system that avoided the constraint imposed by the intimacy of touch, thereby allowing several individuals to be virtually
5 ‘groomed’ simultaneously.

Touch and Virtual ‘Touch’

It is important to appreciate that we still use physical touch extensively in our social interactions. Notwithstanding minor differences between cultures, the pattern of touch is
10 broadly similar across cultures [10]. This, of course, is not to say that we use touch indiscriminately: where we are allowed to touch another person reflects the emotional depth of the relationship we have with that person (Fig. 1). In most cultures, the defining limit for acceptable touch is set somewhere around cousins and good friends (roughly equivalent to the innermost 50 members of our social networks). Beyond that, the areas of the body where
15 it is permissible to touch someone quickly coalesce around the arms and shoulders, and, for strangers, just the hands (hence, the handshake). This seems to correspond to the upper limit on groups that can be bonded by direct haptic contact.

To allow humans to increase group size beyond this limit, touch-based grooming has been supplemented by a range of other behaviours that make up the toolkit of our social
20 world. These behaviours include Duchenne (involuntary) laughter, singing, dancing, feasting, emotionally charged storytelling, and even the rituals of religion. These differ from touch in that they do not involve the intimacies of direct contact, yet all are capable of triggering the endorphin system. Because of this, they make it possible for several individuals to be
‘groomed’ simultaneously. Although some (but not all) of these behaviours occur in many
25 other animals (laughter in rats, singing in birds), these behaviours do not function as social

(and, especially, group) bonding mechanisms in non-primates. In birds, for example, singing typically functions as either a mate-advertising or a group-spacing mechanism [11].

Although the manner and extent to which these behaviours are used in both conventional dyadic and group-level bonding are unique to humans, laughter and singing have some homologues in nonhuman primate behaviour: laughter derives from a modified version of the play grunt of Cercopithecine monkeys and apes [12], while singing exhibits striking similarities to the vocal chorusing observed in New World howler monkeys [13] and chimpanzees. However, in humans, both have evolved into forms that appear especially well suited to triggering an endorphin response. The remaining behaviours, however, seem to be unique to humans, not least because several of them depend on language. I will explore some of the evidence for this in the following section. First, let me establish the fact that these activities do act to bond individuals, both as friends and as members of a small scale community.

Most of our experimental studies have used the Inclusion-of-Other-in-Self (IOS [14]) scale to assess change in an individual's sense of bondedness to the group. Although this 7-point rating scale was originally developed for use in the context of romantic relationships, its simplicity and intuitive nature make it well suited for use in other kinds of relationship contexts, including an individual's sense of belonging to a group. These experiments follow a standard design: subjects rate their bondedness to the other members of the experimental group, undertake a task (e.g. sing, execute simple dance moves, watch a film), and then rate their bondedness to the group again. Fig. 2 summarises the results from experiments representing four different activities: singing [15], dancing [16], religious rituals [17] and emotional storytelling [18]. The exact comparisons differ across the studies (for details, see figure legend), but the experimental designs all contrast a social activity with a control group that undertook a matched non-social activity. In each case, subjects in the experimental group

rated themselves as feeling significantly more bonded to the rest of their group after completing the activity than they did before, whereas the control groups reported a significantly smaller (in some cases, negative) change in rated bondedness.

Beyond this, singing in particular (but dancing as well) has been associated not only with an enhanced sense of social bonding but also with health benefits [19-22]. It is significant that, at least in the case of dance, the enhanced sense of bonding is specific to the individuals with whom one actually dances; there is no effect on the perceived sense of bonding to close friends who are not actually present and involved in the activity [16].

The Neurobiology of Virtual ‘Touch’

To establish that the endorphin system is involved in this bonding process, three experimental paradigms have been used. Because endorphins do not cross the blood/brain barrier [23] and are therefore difficult to assay, an increase in pain threshold has been used as a standard proxy for endorphin uptake (for laughter, singing, dancing, rituals of religion, storytelling). Alternatively, endorphin involvement has been determined indirectly by the administration of an opiate antagonist (naltrexone: dancing, rituals of religion) or directly by PET neuroimaging (laughter, eating). The experimental designs differ between the procedures. For the pain threshold assay and the naltrexone experiments, a between-subjects design has typically been used. In the first case, an experimental group that undertakes the activity of interest is compared with a control group that undertakes an alternate less directly social activity. Pain threshold has been determined using either a cold pressor task or the Roman Chair (or wall-sit) task. The latter is a standard skiing exercise in which subjects sit with their backs against a wall with the knees bent at right angles as though sitting on a chair. In both cases, the outcome measure is the duration for which the position can be held. For the naltrexone experiments, all groups carry out the same activity, but the experimental group

receives a naltrexone dose (administered by mouth) while the control group receives a placebo. The PET experiments use a within-subject design, based on a contrast between a baseline pre-intervention scan and an experimental post-intervention scan.

Fig. 3 plots the change in pain threshold from studies of laughter [24] and dance [16], as well as the results from a naltrexone experiment on dance (righthand set with hatched bar) [25]. There is typically a small negative change in pain threshold in the control condition (i.e. pain threshold is lower after the intervention), and a larger positive change following the experimental intervention. In the naltrexone experiment, subjects performed the same synchronised whole body dance movements in both conditions: those in the placebo condition exhibit the expected increase in pain threshold, but those in the naltrexone condition (hatched bar) exhibit a reduced pain threshold just as they do in the control condition in the other experiments, indicating that endorphins are explicitly involved. In addition, the subjects who took naltrexone felt significantly less socially bonded than those who took the placebo (see also [26]).

PET neuroimaging inevitably provides the strongest evidence for the involvement of endorphins. One problem, of course, is that most of the activities in our social toolkit would be difficult to carry out in the scanner. However, it has been possible to validate the role of endorphins for both laughter [27] and eating [28]. The baseline scan was a conventional passive scan with the second scan given immediately after watching a comedy video with two friends (laughter only occurs in groups) or after eating a prepared dish. Fig. 4 plots endorphin uptake in the orbitofrontal cortex (OFC) as a function of the frequency of laughter after watching a comedy video. The significance of the OFC in this context is that it has direct connections to the amygdala as well as the temporo-parietal junction and the temporal lobe as part of the default mode neural network [29-30], as well as being deeply involved in mentalizing and the management of relationships [31-33].

For some (but not all) of these behaviours, the triggering of the endorphin system appears to derive directly from a physical activity (cf. the ‘runner’s high’ [34]), to which endorphin activation is a natural response. However, the social component invariably involves synchronized behavior, and studies of rowing and dancing show that performing these activities in synchrony doubles the increase in pain threshold compared to the same action performed alone or not in synchrony [16,35-36]. Note that both singing and laughter are also highly synchronized behaviours.

Insights from Receptor Genetics

A number of neuropeptides and neuroendocrines have been implicated in social behavior besides the endorphins. These have included testosterone, oxytocin, vasopressin, dopamine and serotonin. There has, however, been a near-universal tendency for studies to focus on one social neurochemical as though it was the only one involved, notwithstanding the fact that their experimental designs have invariably been confounded by the likely effects of the others. For example, several studies have used hugging and other contact behaviours as the stimulus and measured oxytocin titre as outcome variables [37-38] despite the fact that hugging is likely to trigger an endorphin response and the effect could be entirely due to endorphins. A second issue has been a strong tendency for the research to focus on dyadic relationships (mainly mother-infant bonds, romantic relationships or casual interactions with strangers). In fact, most of our interactions are not with strangers but with a small number of intimates, most of whom are not our parents, children or best friend [9,39]. More importantly, perhaps, even though individual social interactions are necessarily dyadic in form, they are in fact the outcome of three different dimensions of sociality: social predisposition, the dyadic relationship itself and the fact that all dyads are necessarily embedded within an extended

social network such that all our dyadic interactions affect, and are affected by, the behavior and attitudes of these other network members [40].

In an attempt to unpack this, Pearce et al. [41] assayed >1000 subjects for 33 candidate alleles (indexed as single nucleotide polymorphisms, or SNPs) for the receptor genes for the six social neurochemicals listed above that have been implicated in social behaviour. Subjects also completed a series of questionnaires that assayed their social predisposition (Reading the Mind in the Eyes task, Empathizing Quotient and Experiences of Close Relationships scale), the quality of their romantic relationships (Socio-sexual Orientation Inventory and Relationship Assessment Scale) and their embeddedness in a wider social network (the number of intimate friends and the Inclusion-in-Other scale applied to their wider social network). Analysis of the data for a homogenous white British subset (N=757 individuals who declared no current or past psychiatric conditions) revealed significant correlations for (1) social predisposition scores with both endorphin and testosterone receptor genotypes, (2) romantic relationship strength with oxytocin, dopamine and endorphin genotypes, and (3) social network embeddedness with dopamine, serotonin and endorphin genotypes. These results were broadly confirmed in two smaller subsets (140 white British subjects who declared past mental illness and 66 non-Caucasian subjects). The dominance of the endorphin-dopamine system, which commonly work in tandem, is striking. Significantly, the same endorphin receptor gene (OPRM1) also seems to be involved in mother-infant attachment in monkeys [42].

Conclusions

This paper makes two important observations. First, the CNS endorphin system (triggered by social touch involving the CT neuron system) forms the basis for social bonding

in primates in general, and humans in particular. Second, because of the need to bond much larger social communities than those typical among monkeys and apes, humans have adapted a set of behaviours that allow the endorphin mechanism to be activated remotely without need for direct touch so as to increase considerably the number of people that can be
5 ‘groomed’ simultaneously. These social behaviours supplement touch-based processes in ways that allow us both to devote more effort to our most intimate friends (e.g. by adding laughter to touch during interactions) and to reach a wider circle of less intimate friends through less personalized communal interactions such as singing, dancing and religious rituals.

10 It is not known for sure how these behaviors trigger the endorphin system, and it may well differ between behaviours. Some (such as laughter, singing and dancing, and perhaps some of the rituals of religion) may do so peripherally via muscle activity. Alcohol, in contrast, seems to trigger the endorphin system directly (and, indeed, endorphin antagonists are now commonly used as a treatment for alcoholism), eating may either act indirectly
15 through a combination of the heat generated by digestion and stomach wall stretching or directly through taste (e.g. spicy foods), while emotional storytelling probably triggers the pain mechanism in the brain directly since psychological and physical pain are experienced in the same brain region [43-44]. Many, but not all, of these behaviours involve close synchrony and this seems to ramp up the endorphin effect. The importance of synchrony has been
20 widely studied in respect of prosocial behaviour [45-48], and has been noted as playing a significant role in child development [49]. Of particular note in the latter study is the strong signature for this effect in the prefrontal cortex – a brain region that is also both deeply involved in managing social relationships and has a high density of endorphin receptors [50].

In sum, it is important to appreciate that the principal function of the CT system for
25 primates lies in its ability to activate the endorphin system and the role this plays in creating

bonded dyadic relationships, and through this a well-bonded social group based on an interlinked network of these dyadic relationships. We still use this same touch-based system in our more intimate relationships. However, in both primates and humans, the very intimacy of this touch-based process limits the extent to which it can be used to bond large social groups. Humans have discovered a number of other behaviours that trigger the endorphin system, thus by-passing the touch component without need to sacrifice the downstream endorphin-based pharmacological bonding process. Doing so has allowed us to greatly increase the size of bonded social groups.

It is worth noting that during lockdown in the recent COVID-19 crisis, there was an upsurge in the use of these non-contact bonding behaviours, directed at both family and friends. These have included singing from balconies in tenement blocks, online meals or drinking sessions, and the circulation of jokes (many directly related to lockdown) by email and other social media (the latter in far greater volumes than had previously been the case). The fact that we have resorted to these particular behaviours to bolster flagging relationships points to their central importance in the maintenance of the social bonds on which our individual life successes depend so heavily.

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Legends to Figures

Fig. 1. Heat maps of permissible areas for social touch as a function of gender and closeness of the relationship. Blue labels: male; red labels: female. Areas outlined in blue are taboo zones. N=1368 subjects drawn from Finland, Russia, UK, France and Italy. Reproduced with permission from Suvilehto et al. (2015: *Proceedings of the National Academy of Sciences, USA*).

Fig. 2. Change in self-rated bondedness to other experimental group members (indexed by the Inclusion of Other in Self scale) from before to after taking part in a social activity (black bars), compared to that for a control group involved in a matched non-social activity (grey bars). Sources: singing: group singing vs hobbycraft control group [15]; dance: high energy dance movements vs the same arm movements while seated control [16]; ritual: religious versus secular yoga classes [17]; storytelling: emotional drama versus documentary videos [18].

Fig. 3. Mean change in pain threshold (as a proxy for endorphin activation) from before to after engaging in a social activity (black bars) compared to a control involving a matched non-social activity (grey bars) or after a naltrexone dose (hatched bar). Change in pain threshold is measured in seconds. Sources: laughter to comedy video with control non-comedy video, with pain indexed as cold pressor task [24]; dance: high energy dance movements vs arm movements while seated control, with pain threshold indexed by wall-sit task [16]; dance/naltrexone: high energy dance with placebo vs naltrexone control [25].

Fig. 4. Endorphin receptor activity in the orbitofrontal cortex (based on PET neuroimaging) as a function of the amount of laughter for individual subjects watching a comedy video between the two scans. Source [27].

Figure 1

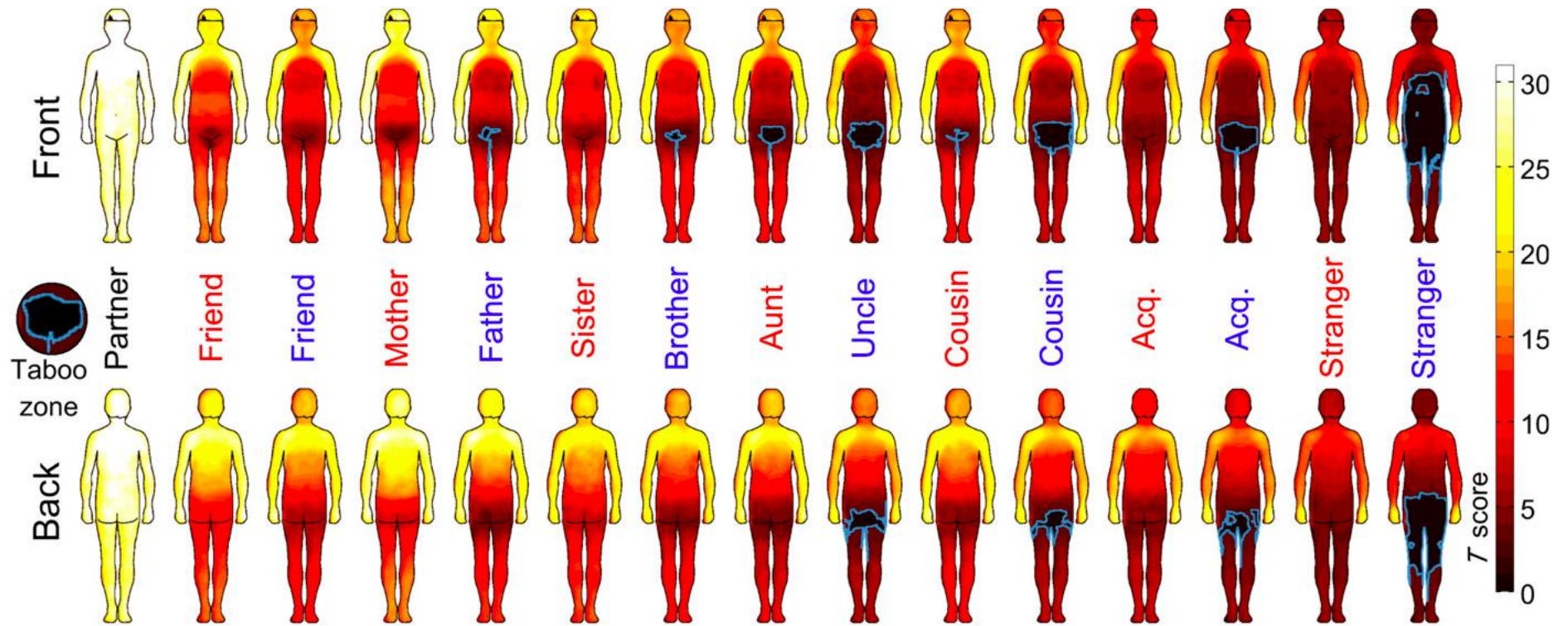


Figure 2

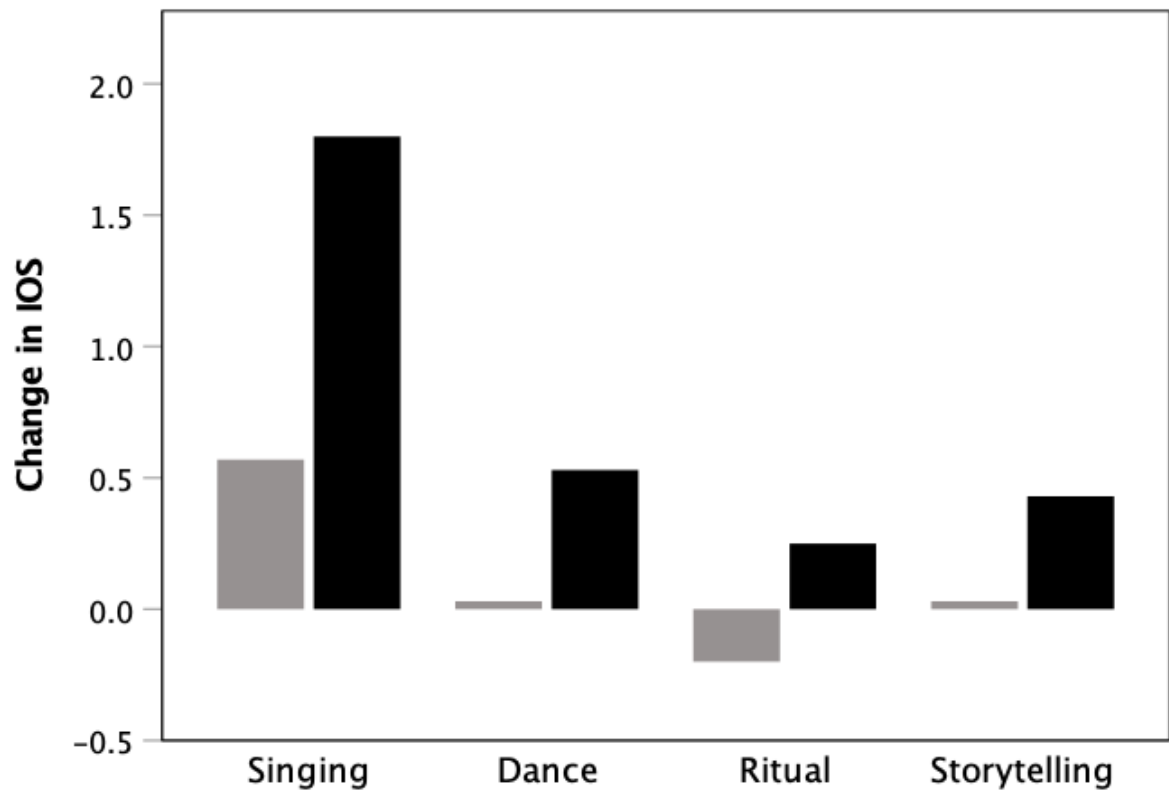


Figure 3

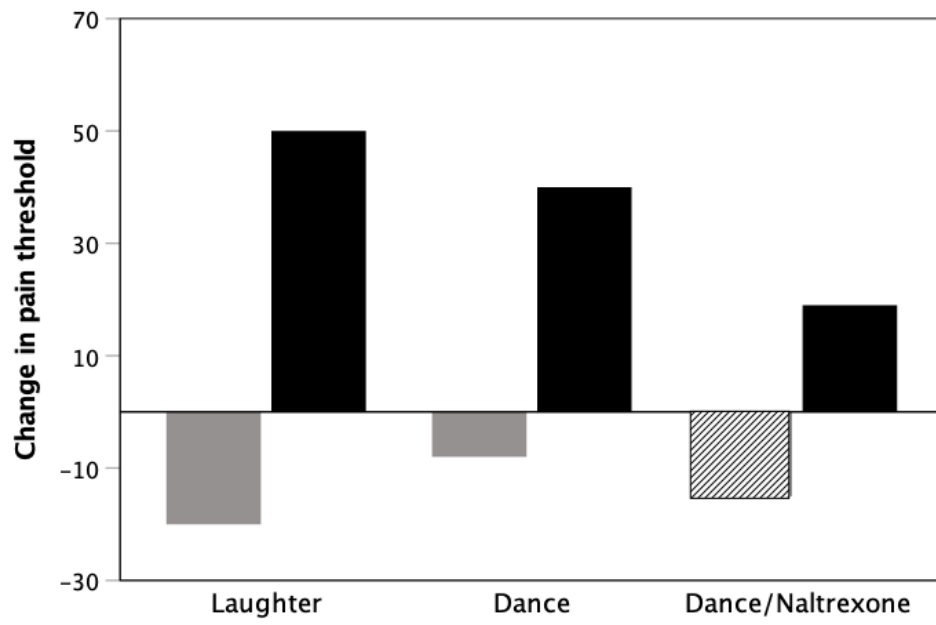


Figure 4

