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Can Less be More? The Impact of Robot Social Behaviour on Human Learning

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Abstract. In a large number of human-robot interaction (HRI) studies, the aim is often to improve the social behaviour of a robot in order to provide a better interaction experience. Increasingly, companion robots are not being used merely as interaction partners, but to also help achieve a goal. One such goal is education, which encompasses many other factors such as behaviour change and motivation. In this paper we question whether robot social behaviour helps or hinders in this context, and challenge an often underlying assumption that robot social behaviour and task outcomes are only positively related. Drawing on both human-human interaction and human-robot interaction studies we hypothesise a curvilinear relationship between social robot behaviour and human task performance in the short-term, highlighting a possible trade-off between social cues and learning. However, we posit that this relationship is likely to change over time, with longer interaction periods favouring more social robots.

1 INTRODUCTION

Social human-robot interaction (HRI) commonly focuses on the experience and perception of human users when interacting with robots, for example [2]. The aim is often to improve the quality of the social interaction which takes place between humans and robots. Companion robots increasingly aim not just to merely interact with humans, but to also achieve some goal. These goals can include, for example, imparting knowledge [11], eliciting behaviour change [17] or collaborating on a task [3, 13]. Studies with these goal-oriented aims often still apply the same principles for social behaviour as those without goals - that of maximising human interaction and positive perception towards the robot. The implicit assumption is often that if the interaction is improved, or the human perception of the robot is improved, then the chance of goal attainment will be increased as well.

In this paper, we focus on learning. In this context, we take learning to be the acquisition and retention of novel information, and its reuse in a new situation. This definition covers 3 areas from each of the 'Cognitive Process' (remember, understand, apply) and 'Knowledge' (factual, conceptual, procedural) dimensions of learning according to the revised version of Bloom's taxonomy [14]. Learning outcomes can depend on many different elements of behaviour, such as motivation [20] and engagement [4], which will also be considered here.

The remainder of this paper is structured as follows. First, studies in which social robots assist humans in learning will be reviewed, with the intention of showing the complex variety of results obtained when relating learning to the social behaviour of the robot (Section 2). Human-human interactions are then considered and are used as a basis to create a hypothesis about the relationship of robot social behaviour and human performance in tasks over both the long and short-term (Section 3). This leads to a discussion of the implications for HRI design in such contexts (Section 4).

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2 MIXED LEARNING RESULTS IN HRI

One area of great potential in HRI is in using robots for education. However, mixed results are often found when using social robots to teach or tutor humans. Despite regular reports of liking robots more than virtual avatars, or preferring more socially contingent robots over those with less social capability, the human performance in learning tasks doesn't always reflect these positive perceptions [11, 12, 17, 22]. Conversely, significant cognitive gains have been found when comparing robots to virtual avatars, with varied amounts of contingent behaviour [15, 16]. Similar effects have been seen in compliance when comparing agents of differing embodiments [1]. Whilst the varied context and content to be learned between these studies could account for many of the differences in results, we suggest that the relationship between social behaviour and learning performance may be more complex than typically assumed.

Commonly, when behavioural manipulations are carried out on one or two cues, such as in a study by Szafir *et al.* varying the gestures and vocal volume that a robot uses, there are clear benefits to the human in terms of performance in learning tasks [26]. However, these positive benefits may be lost, or even reversed when larger manipulations to the social behaviour of the robot are applied, as in [12]. While it may be reasonably assumed that the effect of multiple individual cues is additive, this does not seem to be in accordance with the empirical evidence. Indeed, the proposition that social cues are perceived by humans as a single percept [29] considers individual social cues as providing the context for the interpretation of other social cues (recursively), leading to non-trivial interactions and consequences when multiple social cues are applied. There is thus the possibility that making large manipulations in social behaviour by varying multiple social cues simultaneously does not elicit the benefits that varying each of these cues individually would, as suggested by the data.

Human expectations of sociality will play a large role in an interaction with a robot. It has been suggested that a discrepancy between categorical expectations and perceptual stimuli could account for negative cognitive reactions [19]. We posit that humans don't necessarily expect to interact with a robot exhibiting social behaviours and that the discrepancy between their expectation and the reality of the interaction could create a cognitive reaction which impedes learning. This might explain some results showing a lack of improvement when social presence of an agent is increased (such as when going from a virtual avatar to a robot, as in [10, 17]), or when social behaviour

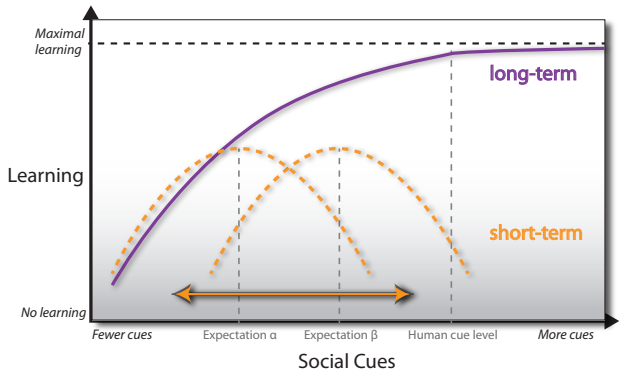

Figure 1: Hypothesised relationship between social behaviour (characterised by *immediacy* for example) as exhibited by a robot and its impact on the learning of a human in both the short and long-term. The position of the short-term curve is dependent on the humans' prior expectations of social behaviour (e.g. α is the expectation of fewer social cues from the robot than expectation β). Over time, these expectations normalise with reality, with increased use of social cues tending to lead to improved learning performance for the human interactant.

becomes more contingent, as in [12]. Expectation discrepancy would consequently lead to changes in the cognitive reaction over time as expectations change, and vary based on individuals, contexts, and so on; this is reflected in Figure 1 and will be expanded upon in Section 3.

Although there are many questions regarding learning in the context of HRI that remain unexplored, it would be useful to try and first create a testable hypothesis to attempt to explain why the results gathered so far are so varied. Whether this lies in social presence differences between virtual and physical robots, or in social behaviour manipulation between robot conditions, the main variable in all of the studies considered in this section is sociality. As such, we now consider how social behaviour might influence learning.

3 SOCIAL BEHAVIOUR AND LEARNING

In order to understand more about the nature of the relationship between social behaviour and learning, literature from human-human interaction (HHI) studies will now be introduced. Learning in the context of HHI has been under study for far longer than HRI, so longer-term research programmes have been carried out, and more data is consequently available.

When exploring the connection between learning and social behaviour in HHI literature, one behavioural measure repeatedly found to correlate with learning is 'immediacy'. Particularly applied to educational contexts, this concept has been long-established and validated across many cultures [18, 24] and age ranges [21]. Immediacy provides a single value definition of the social behaviour of a human in an interaction by characterising conduct in a range of verbal and non-verbal behavioural dimensions [23]. Immediacy could therefore prove a useful means of characterising robot social behaviour in HRI (as in [26]). Further, it has been shown that more immediate behaviours on the part of a human tutor increases cognitive learning gains [28]. However, the exact nature of the relationship between immediacy and cognitive learning gain is debated [5, 28].

Many HRI studies seem to implicitly assume a linear relationship between an increase in the number of social cues used or in social behaviour contingency and learning gains (or gains in related measures such as engagement, compliance, etc). Upon reviewing the literature concerning immediacy between humans, this has sometimes found to be the case [5], but more recent work has shown that this relationship may in fact be curvilinear [6]. A curvilinear relationship could go some way to explaining the mixed results found so far in HRI studies considering task performance with respect to robot social behaviour; it is possible that some studies make the behaviour *too social* and fall into an area of negative returns.

It is hypothesised that the curvilinear nature of immediacy may have been the effect observed in the study by Kennedy *et al.* in which a 'social' robot led to less learning than a robot which was actively breaking social expectations [12]. Over the short term, the novelty of social behaviour displayed by a robot may cause this kind of curvilinear relationship as has been observed in relation to immediacy [6]. As alluded to in Section 2, humans have a set of expectations for the sociality of the robot in an interaction. We would suggest that the greater the discrepancy between these expectations and the actual robot behaviour, the more detrimental the effect on learning. Individuals will have varied expectations, which is manifested in different short-term curves (Figure 1): the short-term curve shifts such that its apex (translating to the greatest possible amount of learning in the time-frame) is at the point where the expected and actual level of social cues is most closely matched. Prior interactions and the range of expectations created could also change the shape of the short-term curve, making the apex flatter or more pronounced depending on the variety of previous experiences.

However, when considering the interaction over the longer-term, such novelty effects wear off as the human adapts to the robot and their expectations change [7, 8, 25]. In this case we suggest that substantial learning gains could be made as the robot behaviour approaches a 'human' level of social cues; having attained a reasonable matching of expectation to reality, the robot can leverage the advantages that social behaviour confers in interactions, as previously suggested [9, 26]. Beyond this level, improvement would still be found by adding more cues, but the rate of increase is much smaller as the cues will require more conscious effort to learn and interpret. These concepts are visualised in the long-term curve seen in Figure 1.

4 PERSPECTIVES

So far, we have challenged the assumption that social behaviour has a simple linear relationship with learning by providing conflicting examples from HRI literature and also by tying concepts of social behaviour to the measure of immediacy from HHI literature. Given the regular use of HHI behaviour in generating HRI hypotheses, the non-linear relationship between immediacy and learning is used to hypothesise a non-linear relationship for HRI, particularly in the short-term (Figure 1).

A series of controlled studies would be needed to verify whether these hypothesised curves are correct. One particular challenge with this is the measuring of social behaviour. It is unclear what it is to be 'more' or 'less' social, and how this should be measured. This is where we propose that *immediacy* could be used as a reasonable approximation. All factors in immediacy are judgements of different aspects of social behaviour, which are combined to provide a single number representing the overall 'immediacy' (i.e. sociality of social behaviour) of the interactant. This makes the testing of such a hypothesis possible as the social behaviour then becomes a single dimension for consideration.

Of course, there are many other issues (such as robotic platform and age of human) which would need to be explored in this context,

but with a single measure approximating sociality this would at least be possible. Providing an immediacy measure for robot behaviour makes it much easier to compare results between studies, allowing improved analysis of the impact of things such as task content and context, which are currently very difficult to disentangle when comparing results between studies. Literature from the field of Intelligent Tutoring Systems may be a useful starting point for future work to investigate specific aspects of learning activities due to their proven effectiveness across many contexts [27].

It should be noted that the aim of this paper is to highlight the potential directionality of the relationships involved between social cues and learning. There is not enough data available to represent the shape of the curves presented in Figure 1 with any great accuracy. The curves have been devised based on the few data points available from the literature, and following from concepts of immediacy and discrepancies of expectation, as explored in Sections 2 and 3.

5 CONCLUSION

We suggest that immediacy could be taken from the HHI literature to be validated and applied to HRI more extensively as it presents itself as an ideal means to facilitate comparison of highly varied social behaviour between studies. The large volume of immediacy literature in relation to learning and other contexts could also provide a firm theoretical basis for the generation and testing of hypotheses for HRI.

In this position paper we have shown through examples from HHI and HRI literature that the relationship between social behaviour and task outcome, specifically learning in the present work, for humans cannot be assumed to be linear. We hypothesise a model in which social behaviour not only has a non-linear relationship with learning, but also a relationship which changes over interaction time. Following the hypothesised model, we suggest that although in the short-term there may be some disadvantages for a robot to be maximally socially contingent, the benefits conferred by social behaviour as proposed by prior work will be seen in the long-term.

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