

Virtual Fitness: Stimulating Exercise Behaviour through Media Technology

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For: *Presence: Teleoperators and Virtual Environments*

Abstract

This paper describes research that is aimed to elucidate our understanding of media technology factors that may help users of exercise equipment to stay motivated for doing regular work-outs. In particular, we investigated the effects of immersion and coaching by a virtual agent on intrinsic motivation and the sense of presence of participants cycling on a stationary home exercise bike. A basic two-by-two within-subjects experimental design was employed whereby participants were presented with a virtual racetrack with two levels of immersion (high vs. low) and two levels of a virtual coach (with vs. without). Results indicate a clear positive effect of immersion on both motivation and presence. The virtual coach significantly lowered the perceived control and pressure/tension dimensions of intrinsic motivation, but did not affect the enjoyment dimension. The presence of the virtual coach also reduced negative effects associated with VEs (e.g., dizziness or nausea).

1. Introduction

It is clear that moderate exercise on a daily basis yields substantial health benefits. The World Health Organisation (WHO) recommends at least 30 minutes of moderate exercise per day. Such regular exercise lowers the risk of obesity, heart disease, some types of cancer, high blood pressure, diabetes and osteoporosis; it reduces depression and improves sleep. Obesity, in particular, has become a major public health concern in much of the developed world, and, increasingly, in some developing countries over recent years. Worldwide more than 1 billion adults are currently overweight - and at least 300 million of them are clinically obese (WHO, 2003). Childhood obesity has taken on epidemic proportions, where prevalence rates have increased 2.3-fold to 3.3-fold over about 25 years in the USA and 2.0-fold to 2.8-fold over 10 years in England (Ebbeling, Pawlak & Ludwig, 2002).

In the USA, more than 60% of the adult population does not get enough physical activity to provide health benefits. In The Netherlands, where the authors have performed the research reported here, only about 20 percent of the population complies with the WHO recommendation of 30 minutes of moderate exercise per day (Hildebrandt, Ooijendijk, Stiggelbout & Hopman-Rock, 2004).

Reasons for exercising too little are varied, but often include a lack of intrinsic motivation – that is, enjoying the activity of exercising for its own sake. This appears to be especially relevant for the use, or rather non-use, of exercise equipment at home. As running or cycling outside is often perceived to be time-intensive, uncomfortable (e.g., bad weather, smog), or even dangerous around places not well-adapted to runners or bikers, a logical alternative is offered by using exercise equipment in the home or in fitness clubs. However, exercising alone and without the support of any media technol-

ogy that provides engaging feedback, the work-out can become quite boring or tedious, and soon the home exercise equipment can be found gathering dust in the attic. Thus, there appears to be a clear need for exercise equipment that is more stimulating and more gratifying to use, such that people's motivational levels will not plummet after the initial enthusiasm that led to the purchase of the exercise equipment has faded away.

The current study deals with the question whether virtual environments (VEs) and biofeedback presented via a virtual coach can help raise motivation for engaging in a healthy regime of physical exercise. We hypothesized that offering a more immersive environment in which the user feels present would heighten the fun the user is having, and would thus have a beneficial effect on the user's motivation. Additionally, we expected that a virtual coach providing biofeedback information on training intensity, specifically heart rate, would increase the motivation as well, as it helps goal-setting and raises perceived control and competency, both of which help boost motivation.

1.1 Motivation

Motivation is the concept we use when we describe the forces acting on or within an organism to initiate and direct behaviour (e.g., Petri, 1981). We usually discern between intrinsic and extrinsic motivation, where intrinsic motivation refers to engaging in an activity purely for the pleasure and satisfaction derived from doing the activity, whereas extrinsic motivation refers to engaging in a variety of behaviours as a means to an end and not for their own sake (Deci, 1975). Intrinsic motivation is often considered more powerful and leading to more stable behaviour than extrinsic motivation and is highly relevant for sports. Below we will discuss how immersion and feedback are thought to influence intrinsic motivation, and in particular enjoyment.

1.2 Immersion and presence

Slater & Wilbur (1997) refer to immersion as the objectively measurable properties of a VE. According to them it is the “extent to which computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of the VE participant” (p. 604). Thus, immersion refers to the system’s ability to accommodate many sensory modalities with a rich representational capability, offering an encompassing field of sensory stimulation while shutting out sensations from the real world.

Presence can be conceptualised as the experiential counterpart of immersion. It has been defined as the sense of ‘being there’ in a mediated environment (e.g., Heeter, 1992; Steuer, 1992) and more recently as the “perceptual illusion of non-mediation” (Lombard & Ditton, 1997) which broadens the definitional scope somewhat, also including social factors. Various empirical studies have demonstrated a positive effect of immersion factors on presence, including field of view, stereoscopic imagery, interactivity, pictorial realism, spatial audio, and haptic feedback (for a review see Sadowski & Stanney, 2002).

Although presence and enjoyment clearly refer to different psychological experiences, a higher sense of presence is generally associated with a higher sense of engagement and more intense enjoyment. In support of this contention, Patel and Nichols (2004) report a significant positive correlation between enjoyment and presence (see also Nichols, 1999; Nichols, Haldane and Wilson, 2000). On the other hand, however, Lin *et al.* (2002) found no significant correlation between the presence and enjoyment subscales in their study on field-of-view effects. The difference in results between the

Nichols *et al.* and Lin *et al.* studies may be attributable to a difference in task. Indeed, Lin *et al.* (2002) suggest that the higher level of interactivity required in the virtual environment used by Nichols *et al.* (2000) could potentially have enhanced the participants' sense of enjoyment.

The history of entertainment media, such as cinema, interactive computer games, or location-based entertainment also shows a clear trend towards higher levels of realism and immersion, with higher reported levels of presence to match (IJsselsteijn, 2003). Generally speaking, it is reasonable to expect a positive relation between presence and enjoyment, provided the media content or task is pleasurable or exciting in itself.

One potential drawback of offering more immersive environments, especially in a sports setting, is the increased risk of simulation sickness, as the information arriving from the various sensory modalities may not always be in agreement. The resulting symptoms, such as cold sweating, dizziness, or nausea, presumably have a negative effect on enjoyment, and possibly on presence.

In sum, we expect more immersive display conditions to be associated with higher levels of presence and enjoyment, thereby boosting participants' intrinsic motivation to exercise, provided that negative effects are kept within acceptable limits.

1.3 Biofeedback

The term biofeedback was originally used to describe laboratory procedures (developed in the 1940s) where trained research subjects were provided with information about their own brain activity, blood pressure, muscle tension, heart rate and other bodily functions that are normally not under our voluntarily control, with the purpose of exert-

ing conscious control over them. Today, biofeedback is often used as a training technique in which people are taught to improve their health and performance by using signals from their own bodies.

In the current experiment, heart rate was measured and, based on this information, feedback was provided to the participant using a virtual social agent, who could either encourage participants to do better, tell them they were doing great, or tell them to slow down a little, if the heart rate became too high. In this way, the coach could both be an extrinsic motivator and at the same time provide feedback on the impact of the exercise. This information is likely to enhance the person's perceived control and competence and stimulates goal-setting and adherence: the information underlines the person's efforts and progress. Thus, we expected the coach to help participants increase their motivation to exhibit the desired target behaviour.

1.4 Related work

The use of virtual environments in stimulating exercise and other beneficial health-related behaviours is clearly in its early stages. Although it is fairly common to have a number of performance (e.g., speed, distance) and physiological (e.g., heart rate, calories used) indicators available when using fitness equipment, virtual environments are still uncommon in most health or fitness clubs. Currently, a typical kind of feedback would be an LED display showing the exerciser's progress along an imaginary track. One early example of the use of virtual environments to promote exercise behaviour is the LifeFitness VR Rowing Machine, which depicts the participant rowing a boat on virtual water, going faster as the participant rows faster. It also allows rowing against a virtual competitor, or being chased by a shark for extra motivation (Fogg, 2003). The

Tectrix VR Bike provides another recent example of a virtual environment being offered as a means of motivating and rewarding people for performing certain exercise behaviours. There are different virtual worlds to explore, and speed and direction are controlled by the participant's movements.

To the authors' knowledge, the only available study directly addressing the effects of simulations on exercise behaviour has been reported by Porcari, Zedaker, and Maldari (1998) – see also Fogg (2003). They performed an experiment where 18 people rode an exercise bike using a virtual environment, and 18 people rode the bike without the simulation. During the 30 minute exercise period used in the study, people that used the virtual environment had higher heart rates and burned more calories, even though both groups showed no significant differences in *perceived* exertion. In other words, the simulated environment led to greater exertion without awareness of the effort. This result is in line with our hypothesis regarding the effects of an immersive virtual environment, where we expect participants to be more highly motivated and cycle faster.

Our work seeks to extend the understanding of the media technology factors that play a role in increasing people's motivation and enjoyment as it relates to exercise behaviour. More specifically, in the above examples, the systems are preconfigured using a regular CRT monitor, thereby limiting its immersive nature, and do not include any kind of coach. Moreover, Porcari et al. (1998) did not include any well-validated measures of motivation or presence in their study that could potentially help in furthering our understanding of the various psychological mechanisms at play. The current experiment aims to explicitly compare immersive and non-immersive types of environmental simulations, as well as to investigate the effects of a virtual coach giving feedback based on participants' heart rate. Dependent variables include subjective measures of intrinsic

motivation and presence, as well as one objective behavioural indicator, that is, participants' cycling speed. Also, an indication of potential simulation sickness is included through the use of the ITC-Sense of Presence Inventory, 5 items of which form a scale on Negative Effects.

2. Method

2.1 Design

A basic two-by-two within-subjects experimental design was employed whereby participants were presented with two levels of Immersion (high vs. low) and two levels of Virtual coach (with vs. without).

2.2 Participants

Twenty-four employees of Philips participated in the study, none of whom engaged in frequent physical exercise. Male/female distribution was even; their average age was 41.3 years. All participants were naïve to the hypothesis under test.

2.3 Equipment and Setting

The experiment was conducted in the HomeLab (see: <http://www.research.philips.com/technologies/misc/homelab/index.html>), at the Philips Research laboratories in Eindhoven, The Netherlands. HomeLab is a future home-simulation, a test laboratory that looks like a normal house and thus provided us with a relatively natural context in which to test the behaviour of the participants using the home fitness application. The experiment was conducted in a room, which was dark-

ened for the purpose of the experiment to avoid bright sunlight unpredictably influencing the visibility of the screen. Participants were asked to seat themselves on a racing bicycle placed on a training system with variable resistance. The bicycle was placed in front of a wall-mounted screen on which the environment and the coach were displayed using a projector (see Figure 1). We chose to use projection rather than a CRT-based display, as it allowed for a larger field of view to be displayed, which in previous research has been shown to be more effective in engendering a sense of presence in participants (e.g., Prothero & Hoffman, 1995; IJsselsteijn, de Ridder, Freeman, Avons & Bouwhuis, 2001).

[Figure 1 approximately here]

2.4 Stimuli

The high immersion condition showed a fairly detailed interactive computer-generated visualization of a landscape through which the participant was able to cycle. Interaction with the VE took place via the exercise bike using handlebars for direction and biking velocity for speed of navigation through the virtual landscape. We used the Tacx VR Trainer software (<http://www.tacx.com/>), which is commercially available for home exercise bikes, and allows for controlling both speed and direction. The low immersion condition showed an abstract picture of a racetrack in bird's eye view, with a dot indicating the position of the biker (see Figure 2). Interaction with the environment was less rich since participants did not have to use the steer to stay on track, nor could they influence the velocity of the dot on the track (although most participants were not aware of this, as they indicated in the debriefing). The reason for using this type of visualiza-

tion was that we wanted to use a realistic baseline condition that is exemplary of the kind of feedback that is currently available on exercise equipment. Thus, when comparing the low and high immersion conditions, multiple immersion variables that are known to affect presence are manipulated, including interactivity, pictorial realism, and first- vs. third-person point of view.

[Figure 2 approximately here]

In the condition with virtual coach, a female virtual agent appeared every minute (see Figure 3). She gave feedback to the participant, based on heart-rate information measured with a heart rate monitor chest belt. The feedback was offered using a pre-recorded female voice to which the (lip)movements of the social agent were synchronized, and simultaneously displaying the text in a small cartoon-like text-balloon. In the conditions without the virtual coach this image did not appear.

[Figure 3 approximately here]

2.5 Dependent variables

The main dependent measures were intrinsic motivation and presence. Motivation was measured using an existing, well-validated questionnaire, the Intrinsic Motivation Inventory (IMI), consisting of six subscales: (i) Interest/enjoyment – which is the most central one to intrinsic motivation, (ii) Perceived Competence, (iii) Value/Usefulness, (iv) Perceived Control/Choice, (v) Felt Pressure and Tension, and (vi) Effort. For measuring presence various methods have been used or proposed to date (for a recent com-

prehensive review, see van Baren & IJsselstein, 2004). The ITC Sense of Presence Inventory (Lessiter, Freeman, Keogh, & Davidoff, 2001) provides sufficient sensitivity, while having proven reliability and validity. It consists of four subscales: (i) Spatial Presence, (ii) Engagement, (iii) Ecological Validity, and (iv) Negative Effects. Besides this, heart rate and velocity of the participant were also measured and recorded. The heart rate was used as input for the coach's directions (i.e., it was *not* used as a dependent variable); average velocity was considered as a corroborative behavioural measure of motivation, since one would expect participants to work harder during their exercise when motivation is higher, in line with results reported by Porcari (1998).

2.6 Procedure

Participants – in sports clothing – received a short introduction upon entering the exercise room. After putting on the chest belt for easy heart rate measurement, they mounted the bicycle for the first session. The total procedure consisted of four sessions, one for each experimental condition, the order of which was fully counterbalanced. After every session participants filled out the IMI and ITC-SOPI, which also gave them 10 minutes to recover from their exercise. The total experiment took about 1.5 hours to complete.

3. Results

For both the ITC-Sense of Presence Inventory (ITC-SOPI) and the Intrinsic Motivation Inventory (IMI), components were computed based on the factor structures that were validated in earlier studies. Subsequently, repeated measures analyses of variance (REMANOVA) were performed on these components according to the full model, with

immersion (high vs. low) and virtual coach (with vs. without) as independent within factors. Significance was assumed at the $p \leq 0.05$ level. Results will be reported for intrinsic motivation components first, then for presence. Lastly we will report bivariate correlations between the various components.

3.1 Intrinsic Motivation

The six IMI components were all subjected to full model REMANOVAs. Four scales (Interest/Enjoyment, Perceived Competence, Value/Usefulness, and Perceived Control) showed significant effects of immersion: all scores were higher for high immersion. These last two scales also showed a significant effect of the virtual coach, as did the Pressure/Tension scale: Value/Usefulness was higher, Perceived Control and Pressure were lower with the coach present. Finally, the Effort/Importance scale did not show any significant results. No significant interactions were found. Means of the most important scales are visualized in Figure 4; statistics are reported in Table 1.

Average velocity was used as a corroborative behavioural measure of motivation. Indeed velocity scores showed the same pattern of results as the questionnaire data did. There was a main effect of immersion $F(1,23)=65.73$, $p<.001$, with average speed higher in the high ($v=23.8$ km/h) vs. low ($v=20.6$ km/h) immersion condition. The virtual coach had no significant effects on velocity.

Table 1. Repeated measures analyses of variance of motivation components (IMI)

	Immersion		Coach		Imm x Coach	
	F	p	F	p	F	p
Interest/Enjoyment	29.14	.00	0.30	.59	1.49	.23
Perceived Competence	7.69	.01	0.68	.42	0.09	.77

Value/Usefulness	9.01	.01	6.61	.02	0.09	.77
Perceived Control	22.07	.00	37.41	.00	1.70	.21
Pressure/Tension	3.89	.06	21.78	.00	2.93	.10
Effort/Importance	1.17	.29	3.85	.06	0.09	.77

[Figure 4 approximately here]

3.2 Presence

Secondly, four separate REMANOVAs were performed with the components of presence (Spatial Presence, Engagement, Ecological Validity, and Negative Effects) as dependent variables. Three components showed strong and highly significant effects of immersion, indicating that Spatial Presence, Engagement, and Ecological Validity were higher for high immersion. The effect on the Negative Effects subscale was smaller, but also significant. This component also showed a significant effect of coach, as did Spatial Presence; participants reported more presence and less negative effects in the condition with the virtual coach present. No significant interactions were found. Means are visualized in Figure 5, results of the ANOVAs are reported in Table 2.

Table 2. Repeated measures analyses of variance of presence components (ITC-SOPI)

	Immersion		Coach		Imm x Coach	
	F	p	F	p	F	p
Spatial Presence	72.22	.00	9.45	.01	1.66	.21
Engagement	90.20	.00	2.62	.12	2.85	.11
Ecological Validity	68.08	.00	1.53	.23	0.45	.51
Negative Effects	4.16	.05	13.49	.00	0.38	.54

[Figure 5 approximately here]

3.3 Correlations between motivation and presence

We were also interested in testing relationships between the various components of motivation and presence. For this reason, bivariate correlations were computed. In summary, we found considerable correlations between the motivation scales Interest/Enjoyment, Perceived Competence, Value/Usefulness, and Perceived Control (.39-.69, $p < .01$), high correlations between presence scales – Spatial Presence, Engagement, and Ecological Validity (.77-.84, $p < .001$), and some significant correlations between presence components (Spatial Presence, Engagement and Ecological Validity) on the one hand and motivation components (Interest/Enjoyment, Perceived Control, Pressure/Tension) on the other (.24-.71, $p < .05$), with the highest correlation ($r = .71$) not surprisingly being between the Interest/Enjoyment scale of the IMI and the Engagement scale of the ITC-SOPI, as they are both measuring similar constructs. Spatial Presence and Enjoyment were also highly and positively correlated ($r = .67$).

4. Discussion

The results of this study show that offering a more immersive environment in which the user feels present heightens the enjoyment the user is experiencing, and thus has a beneficial effect on the user's motivation to engage in exercise behaviour. In the highly immersive environment, where the presence experience was stronger, participants reported more interest and enjoyment, more perceived competence and control and, perhaps even more importantly, they cycled faster. These results are in line with our expectations, and extend the results reported by Porcari et al. (1998), who also showed that participants

did a more intensive work-out when interacting with a VE, indicating higher intrinsic motivation.

The effects of the virtual coach providing biofeedback information were somewhat less straightforward. Against our expectation, enjoyment - the most important indicator of intrinsic motivation - was not higher with the coach. This could be attributed to the fact that the coach may act more as an extrinsic motivator than as an intrinsic one, thus not heightening enjoyment in the activity as such. However, an effective extrinsic motivator is still expected to have an effect on training intensity (cycling speed), our objective indicator of motivation. This was not the case in our experiment. Thus, the virtual coach in its current incarnation may not be very effective in engendering a motivational effect. However, various alternative explanations need to be considered before we can discard virtual coaches as an effective means of motivating people to do exercise. For example, coaching form and style (e.g., dominant or cooperative), the informational content, the types of messages used (e.g., directive vs. non-directive), gender, age, or personality effects are all potentially relevant variables to be considered. We are currently exploring these issues in more detail in a series of follow-up studies, also taking extrinsic motivation and the experienced level of social presence of the coach explicitly into account as dependent measures.

The presence of the coach giving exercise intensity information based on heart rate did lower perceived pressure and tension, which is a positive effect. Apparently, participants felt comfortable in relying on the coach's directions, which took away some of the potential stress or uncertainty and may have helped in goal-setting and judging one's own behaviour against the desired target behaviour of doing a good work-out. In

line with this interpretation of the results, the presence of the coach also lowered perceived control.

Additionally, and interestingly, the virtual coach also lowered the negative effects that participants reported (as a subscale of the ITC-SOPI) in both the immersive and non-immersive conditions. This may indicate that the presence of the coach ameliorated some mild simulation sickness symptoms (i.e. headache, nausea, dizziness, eye strain, tiredness) associated with both types of simulated environments. This effect may be explained by the fact that the coach provides somewhat of a distraction, although it probably affected the two conditions in different ways. In the case of the low-immersion condition it is making the experience as a whole somewhat richer and less boring, whereas in the high-immersion condition, it can possibly resolve some of the potential sensory conflicts, by providing a stable visual stimulus within a visual field that is otherwise dominated by the optic flow of forward movement through the virtual landscape. In future studies we hope to further investigate whether the effect of a virtual coach on diminishing simulation sickness symptoms related to immersion is robust, and if so, what would be the most likely psychological and physiological mechanisms underlying such an effect.

Finally, in our study spatial presence and enjoyment were positively correlated ($r=.67$), in line with results found by others (e.g., Nichols *et al*, 2000). Although no causal inferences may be drawn from such correlational data, we feel that as long as the content in itself is enjoyable, manipulating media form factors that will increase the psychological impact of the medium and engender a higher sense of presence in the participant, will likely result in higher levels of enjoyability as well.

In sum, our results support the notion that immersive virtual environments can play a very positive role in encouraging, motivating and enabling individuals to engage in physical activity, helping them to manage their weight and improve their health. As virtual environments are also likely to appeal to children and adolescents, this type of media technology can provide a useful tool in combating childhood obesity. Identifying and disentangling the various media form and content factors that play a role in creating situations that reward and motivate people to engage in exercise and other positive health-related behaviours will remain a focus for our future research endeavours.

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List of Figure Captions

Figure 1. Composite photograph of the experimental setup, with the stationary racing bicycle placed in front of the wall-projected virtual environment. Participants' viewing distance was approximately 2.20m, with an image size of 1.60m by 1.10m.

Figure 2. Low Immersion condition. The image depicts the racetrack from bird's eye perspective with a moving dot representing the participant.

Figure 3. High Immersion condition with virtual coach. The virtual environment was generated in real-time using the Tacx T1900 'i-magic' VR Trainer software. The Virtual Coach was provided by Philips PDSL, and mixed in with the virtual environment (both in the high and low immersion conditions) using a video mixer.

Figure 4. Means of Interest/Enjoyment, Pressure/Tension, and Perceived Control components of the IMI, for all experimental conditions

Figure 5. Means of Spatial Presence, Engagement, Ecological Validity, and Negative Effects components of the ITC-SOPI, for all experimental conditions

Figure 1.



Figure 2.

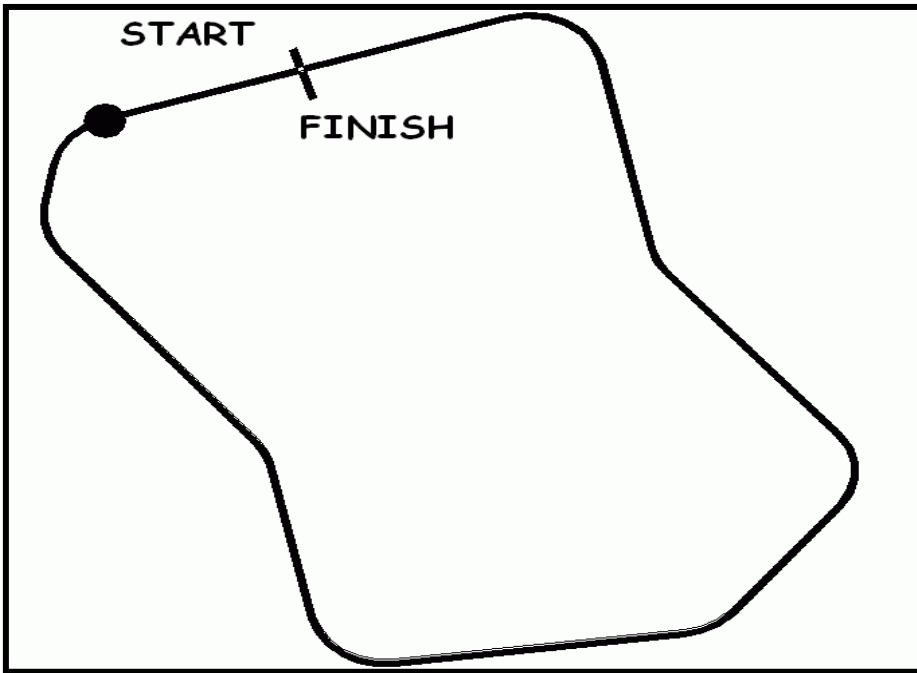


Figure 3.



Figure 4.

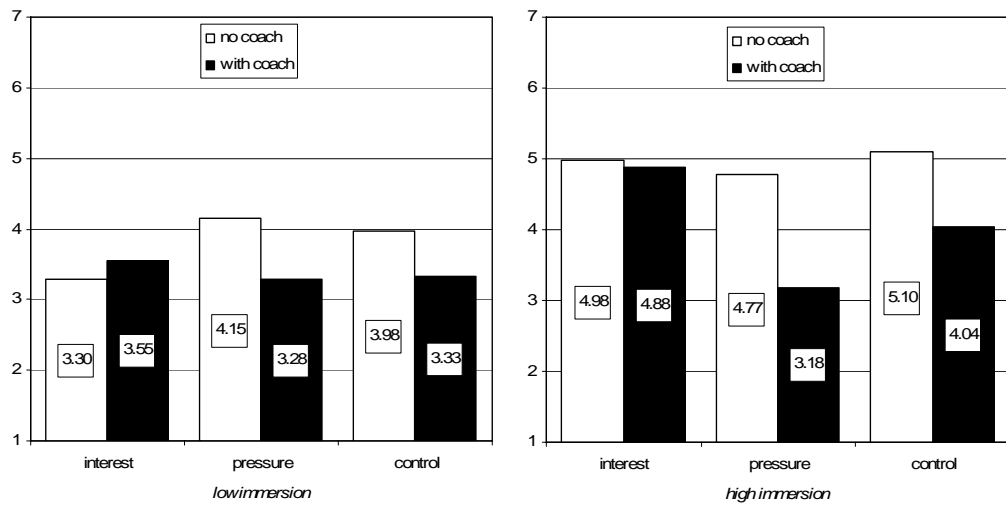


Figure 5.

