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The effectiveness of online instructional videos in the acquisition and demonstration of cognitive, affective and psychomotor rehabilitation skills

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Abstract
The use of instructional videos to teach clinical skills is an ever growing area of e-learning based upon observational learning which is cited as one of the most basic yet powerful learning strategies. The aim of the current study is to evaluate the effectiveness of online instructional videos for the acquisition and demonstration of cognitive, affective and psychomotor skills amongst Undergraduate students, throughout formative assessments with two different durations of instructional videos. The research suggests that the use of videos to support traditional learning should be encouraged, whilst a conclusive evidence - base for their usage has not yet been established they are a medium which is likely to benefit a proportion of a cohort, and it is very unlikely that they will be harmful to students' learning.

What is already known about this topic:

- E-learning is becoming increasingly popular within educational domains.
- Observational learning is one of the most powerful learning strategies for humans that can be enabled further by technology.
- As technology becomes ubiquitous there are less barriers for the delivery of e-learning.

What this paper adds:

- Instructional videos can be used to successfully aid traditional learning for cognitive, affective and psychomotor skill acquisition.
- There is a trivial difference between two different duration of instructional videos, both having positive effects overall
- Formative assessment throughout the experimental phase each

year significantly correlated with the student's end of year summative assessment.

Implications for practice

- The use of instructional videos is possibly beneficial and very unlikely to be harmful to students.
- Instructional videos should be designed with a working knowledge of CLT and MMLT wherever possible.
- Effect size statistics reveal substantially more about a finding than the *p* value alone. Whilst the effect may not be significant the increases observed have real world implications on student attainment.

Introduction

The growing adoption of e-learning technologies within the education of health professionals has risen progressively throughout the past five decades (Triola et al., 2012). Principally due to the literature regarding e-learning citing the method as a promising alternative to the traditional classroom setting, it is generally concluded that e-learning will improve learning, and is equivalent to or in some cases is superior to traditional teaching methods (Chen, 2011, McNulty et al., 2009a and Zhang et al., 2006).

The adoption of e-learning within a health setting presents a unique set of problems as the complexity of teaching a hands-on profession in a traditional academic setting, rather than a purely theoretical or philosophical subject have been documented in previous literature (see Perry, 1999) and it would be a fair assumption that these challenges carry over into the realm of e-learning. As a result of the challenges posed educators have responded by adopting various e-learning methods in an attempt to standardise and enhance the efficiency of teaching (Veneri, 2011). Amongst these methods video has been highlighted as one of the most consistently used methods, however video is a medium that has been used in academic health for a long time and is well established as an accepted technique (Schittek Janda et al., 2005). Newer technologies currently available have enabled the electronic distribution of videos that can illustrate abstract cognitive processes or concepts and this is responsible for bringing video back to the forefront of learning and teaching within medical education (Chen, 2011, McNulty et al., 2009b and Wouters et al., 2007). Although videos are still being used within their typical settings to present theoretical content, there is an emerging area pertaining to the use of instructional videos to teach psychomotor skills (McNulty et al., 2009b and Smith, 2011).

The traditional strategies used to teach psychomotor skills include the use of lectures, textbooks, self-instruction and live demonstration (Smith, 2011). Learning motor skills by watching a live demonstration has long been recognised as a successful and well-researched instructional method for over 30 years

(Wouters et al., 2007). Previous instructional videos of demonstrations were either broadcast 'off-line' through TV or stored on CD-ROMS, and were not generally made available to students, included only when the teacher felt it was appropriate for the course (Green, 2003, Schittek Janda et al., 2005 and Zhang et al., 2006). However, even though the technology now makes wider distribution possible, introducing videos through e-learning does not necessarily ensure effective and efficient learning (Chen, 2011 and Kala et al., 2010). More significantly there is limited conclusive evidence demonstrating its effectiveness for teaching clinical skills (Bloomfield et al., 2010). The acquisition of psychomotor skills among students and the relationship to teaching methodologies is a relatively new area of research in health care education (Veneri, 2011) and in general multimedia educational research has been characterised by inconsistency which have led to inconclusive findings with relation to the effect that multimedia resources can have on the learning process (Samaras et al., 2006). Tallent-Runnels et al., (2005) expand on this further stating that there is a serious mismatch between the technological features that are emerging and the pedagogical teaching principles relating to e-learning. Pedagogical principles provide a theoretical structure that guides strategies and activities that in turn form the foundation of good educational practice, within e-learning these are principally focused and implemented by the instructional design (Alonso et al., 2005, 2008 and Kala et al., 2010). Instructional design has developed in combination with three basic learning theories; behaviourism, cognitivism and constructivism (Alonso et al., 2005 and 2008). Each of the three theories focus on different perspectives of learning, behaviourist theory centres around observable behaviour (objectivity), cognitivism on unobservable behaviour (subjectivity) and constructivism identifies the importance of new knowledge construction and learner-centred experiences (Kala et al., 2010). Whilst it is generally acknowledged that the cognitive and constructivist approaches have dominated the evolution of learning theories, behaviourism is perhaps the most pertinent to the fundamental acquisition of psychomotor skills.

Observational Learning

Learning by observing and imitating others has long been recognised as one of the most basic yet powerful learning strategies for humans (see Gog et al., 2008). Skill acquisition takes place when the behaviour, strategies, or thoughts of observers are moulded after viewing experts who perform flawless and error free movements (Wouters et al., 2007).

A significant challenge within multimedia learning concerns the notion as to whether it is possible to promote constructivist learning from passive media (Mayer, 2002). Mayer's (1999) Multimedia Learning Theory (MMLT) provides the most definitive and well-evidenced instructional design approach (see Mayer and Moreno, 1999) and is founded on all three of the main pedagogical theories and the extensively tested and substantiated Cognitive Load Theory (CLT) (Paas et al., 2010). Therefore to maximise the instructional effectiveness of multimedia it

is useful to be guided by the research-based theory of how people learn and to connect applications with evidence and theory (Mayer, 2002).

Psychomotor Classification

A dominant theoretical classification of learning objectives that incorporates a psychomotor element that is ecologically valid given it is derived to provide taxonomy for the analysis of University level education, and has construct validity given its foundations in behaviourism is Bloom's Taxonomy (Ferris and Aziz, 2005). Bloom's taxonomy divided educational objectives into three domains (Cognitive, affective and psychomotor) each with an internal hierarchy.

The psychomotor domain was omitted from the original publication and the team led by Bloom never published a hierarchical taxonomy (Ferris and Aziz, 2005) and whilst it is acknowledged that no single theoretical foundation exists for instructional design a blending of behaviourist and cognitive approaches seems inevitable (Deubel, 2003). Many authors have sought to extend and complete Bloom's Taxonomy so that it fully encompasses a psychomotor domain; however there has not been an agreed consensus of opinion regarding the classification of this domain. Simpson (1967) attributes this to the involvement of the other two domains within the psychomotor domain that create a 'special problem of complexity' when developing a classification system for it Dave (1970). Dave proposed a taxonomy that has five levels and bases its foundations clearly upon behaviourist theory, with the first level being *imitation* and the ascending pathways leading to *naturalisation* of the activity and skill.

There has been a dearth of proposed psychomotor classifications since, however one exception to this is a classification by Dawson (1998) who sought to extend Bloom's Taxonomy's. Dawson's taxonomy is similar in nature to that of Dave's (1970) and provides a hierarchy from observation through to mastery. Dawson, (1998) aligns the pertinence of the psychomotor domain to sport, craft and trade training as well as the objectives of the performing arts and those professions that require manual dexterity such as laboratory practice and surgery. The domain builds on the behaviourist approach as there is a clear pathway for the development of higher-order learning given the mastery component of the hierarchy, however this is purely theoretical as the paper by Deubel, (2003) stated that it is still yet to be proven. As a result despite the extensive range of available taxonomies to draw from the work of Dave (1970) and Dawson (1998) are the most appropriate classifications of the psychomotor domain when compared to the structure, purpose and intended recipients of Bloom's taxonomies.

Instructional Video

The use of instructional video is growing considerably and whilst there are a plethora of papers (ranging from the safe use of wrenches to assembly of electrical circuitry) that investigate the role of an instructional video with a

practical task, only a limited proportion of research articles quantify the psychomotor component. From the range of studies conducted a selection relate to the topic of investigation within this proposed study. Salyers, (2007) conducted a quasi-experimental study with nursing students to determine the effects of traditional and web-enhanced instructional approaches that included instructional videos. Whilst their sample size was limited to 36 students the researchers quantified the student's cognitive, psychomotor and satisfactory scores from the two approaches. The study demonstrated that the students in the web-enhanced group achieved significantly higher scores on the final cognitive examination, achieved better scores on the psychomotor skills examination although not significantly so but were not as satisfied with the course as their traditional delivery colleagues. The results of the study yield interesting conclusions that support the previous learning presented with the exception of the affective domain that the authors accredit to the technological learning environment, however the fact remains that those who participated in the web-enhanced format did perform better (Salyers, 2007). Another study involving nursing students was conducted by Bloomfield et al. (2010) to assess the efficacy of an instructional hand-washing video when compared to a control group with a traditional instructional format. The study had a far higher sample size than the previous study with 242 students of mixed gender, age, educational background and first language recruited (Bloomfield et al., 2010). Due to the nature of the task the study was brief and the follow up measures (knowledge and skill performance) where conducted at 2 and 8 weeks to determine the retention of knowledge. There were no significant differences in the cognitive and psychomotor skill performance scores between the two groups at the 2-week follow-up with significant differences present at the 8-week follow-up (Bloomfield et al., 2010). Whilst the findings of the study were not as robust as the study conducted by Salyers, (2007) the findings reveal that the instructional video is a viable alternative for instructing the hand-washing skill and further supports MMLT effectively by demonstrating increased retention due to the deeper learning theorised by Mayer, (2002). The application of the findings by Bloomfield et al. (2010) are given further educational scope as Ahn et al. (2011) conducted a study examining the effect of a 'reminder video' viewed on their mobile phone on retention of cardiopulmonary resuscitation (CPR) and automated external defibrillation (AED) skills. Seventy-five male students were randomly assigned to the video-reminded or the control group and those in the experimental group received text messages every two weeks encouraging them to view the 180-second long 'reminder video'. Three months following their initial training students in the video-reminded group demonstrated significantly more accurate CPR and AED skills than their control counter-parts. As an additional measure the video-reminder group also demonstrated significantly higher self-assessed confidence and willingness to perform CPR skills than those in the control group (Ahn et al., 2011). The research presented is consistent with the conclusions of literature cited initially and whilst it can be viewed as an appropriate substitute it is evident that instructional multimedia for cognitive and psychomotor learning

within higher education appears to be most effective when it is delivered in addition to traditional classroom instruction (Smith, 2011). Although the literature presented earlier was based upon the broad range across all e-learning approaches the acquisition and demonstration of psychomotor skills has a growing evidence base. However, the conclusions of a systematic review conducted by Veneri, (2011) supported by the work of medical and allied health educators state that, the usage and effectiveness of computer assisted learning (e-learning) particularly with regard to higher order thinking and psychomotor skills requires further research.

The Current Study

The current study aims to evaluate the efficacy of online instructional videos (of differing durations) for Undergraduate students to determine the effect that they have upon their ability to acquire cognitive, affective and psychomotor skills. The students will be assessed formatively and evaluated on a group and individual basis.

Methodology

The study adopted a longitudinal, blinded, crossover design and took place over an 18-week period within two consecutive years. The 18-week period was divided into three, six-week blocks to ensure parity between the three experimental conditions; control, short and long videos. Lecturers who were blinded to the study assessed students formatively each week.

Ethics

Ethical clearance was granted by Durham University School of Education, Ethics Committee and Teesside University Research Ethics Committee, the former as the lead researcher's supervising institution and the latter as the institution where the research would be conducted.

Participants

Ninety-eight students participated in the study across two academic years, sixty females and thirty-eight males with a mean age of 20.87 (SD = 4.53). All participants were fully informed about the study and were asked to voluntarily complete a written consent form prior to participation in accordance with British Educational Research Association (BERA) guidelines (2004). Each participant was informed of their right to withdraw and their right to obtain a copy of the results following the completion of the study.

Research Design Considerations

The crossover design was based upon a Latin square (Table 1) that ensured all students participated within each of the three conditions throughout the module to ensure no group of participants was disadvantaged. Students were requested not to share resources with friends outside their seminar group to minimise the experimental treatment diffusion and threaten the internal validity. Students did

not receive scores during the period to prevent compensatory rivalry/equalisation, resentfulness or demoralisation between groups, particularly from those who begin with a resource and experience the control condition subsequently. The lecturers responsible for the academic delivery and formative assessment of the module remained consistent throughout both of the research periods.

Insert table 1 here

Instructional Videos

Two groups of instructional videos where created that are both based upon the work of Smith, (1998) which forms the foundation of the teaching structure for the rehabilitation module. Smith, (1998) separates the rehabilitation process into three distinct sections within the rehabilitation continuum: Early, Intermediate and Late and provides examples of exercises that are appropriate for that stage and the criteria that need to be achieved in order to progress through the continuum. Each of the exercises was supported with further literature to provide up to date definitions and information to foster an evidence-based approach.

Twenty-five short duration videos ranging from 55 to 118 (1.58 minutes) seconds were created for one group and five previously recorded and produced longer duration videos ranging from 629 (10.29 minutes) seconds to 1094 (18.14 minutes) seconds were used for the second group. The short duration videos were designed in accordance with the principles for instructional design set out by Mayer (2008); the long duration videos were produced prior to these criteria being applied and adhere to all except the redundancy principle, as on-screen text was used with narration. It was not deemed feasible to reshoot and reproduce these five videos. The production value of the videos is not a distinct criterion within instructional design; however it is important to acknowledge that the videos had differing production values due to the software and resources available at the time of production. As a result the short videos have benefitted from more recent software and greater expertise throughout their production.

All videos where converted into the same format (.wmv) and attempts were made to provide similar resolutions and streaming rates for the participants for consistency. The videos were disseminated online with an adaptive release ensuring groups had access to each respective group when the crossover design dictated.

Experimental and Control Conditions

During the phases of data collection there was a minimum of three seminar groups within the Rehabilitation module (A, B and C). In the second year of data collection there were four seminar groups, two of these were amalgamated to ensure there were three distinct groups. Two of these groups will have access to the different instructional videos whilst the control condition within the study will

not be provided with any other additional materials than those that are already available to all students.

Procedure

The annual format of the module after the initial 6 weeks of pitch side management and introduction to rehabilitation theory requires the students to produce rehabilitation sessions in groups, for a specific peripheral joint at a particular stage of the rehabilitation continuum. The students have one week to formulate the sessions traditionally relying on standard resources, in the lesson the students will conduct the sessions and gain formative feedback from the tutor and their peers.

Instruments

The students were assessed formatively by each lecturer using a 10 cm Likert scale (with no numerical or written reference points) for each of the five criteria that the end of year practical examination is scored upon devised from Smith (1998); these encompass cognitive, affective and psychomotor domains. The students received formative feedback verbally at the end of each session; the completion of the scales did not increase the workload of those involved.

Data Analysis

Each Likert item was measured with a standard 30 cm ruler to an accuracy within one millimetre, all scales where measured by the same person enhancing reliability. Totals where summed and averages calculated in Excel (Microsoft Excel for Mac 2011, Microsoft Corporation) for each of the fifty-four data collection points within each year, one-hundred and eight in total across the experimental period. In addition to the Null Hypothesis statistical tests, Cohen's Effect Size Statistic's were calculated using a macro enabled spreadsheet (Hopkins, 2006) and evaluated using the descriptors and magnitude-based inferences provided by Batterham and Hopkins, (2005).

Although the scores were gained within groups, they were assigned to each individual (within the group) to provide an individual total for each participant for each experimental condition. The students worked in different groups each week ensuring no individual total would be the same. In essence each participant had the potential for six separate scores within each experimental phase, yielding an overall total for each phase. As a result participants were excluded from the study during data analysis if they attended less than 50% of the sessions during each of the experimental conditions of the study; this resulted in 19 students being excluded from the data analysis.

Results

In order to investigate the variance between the three experimental groups a between-between Univariate Analysis of Variance (ANOVA) with Tukey post-hoc tests was used to analyse the formative scores of the three groups. The results demonstrate that there was no statistical difference between the three

experimental groups [$F_{2,104}$ =*0*.17, p =.85] despite the observable difference in means between the control and videos groups in Figure 1.

Insert Figure 1 here

The mean difference in formative assessment between Control and Long was 3.23 (95% confidence interval -1.41 to 7.86, p =.25) and Control and Short was 2.88 (95% confidence interval -1.72 to 7.48, p =.30). The magnitude of this effect for each comparison was small (effect size 0.27: -0.20 to 0.73) and (effect size 0.21: -0.19 to 0.60), respectively. The probability (% chances) that the true population effect is beneficial/ trivial/ harmful is 61.8/ 35.8/ 2.4 and 51.1/ 46.6/ 2.2: therefore the interventions are possibly beneficial and very unlikely to be harmful. When the two video groups where compared the mean difference in formative assessment between Long and Short was 0.65 (95% confidence interval -3.29 to 2.59, p =.84). The magnitude of this effect was insubstantial (effect size 0.05: -0.42 to 0.52). The probability that the true population effect is beneficial/ trivial/ harmful is 25.6/59.8/14.7: therefore the difference between the two video groups is predominantly trivial.

Individuals
A Two-way *factorial* ANOVA was performed to analyse the differences, if any between the individual students. The findings demonstrate that there is a statistical difference between the participants ($F_{97,1051}$ =3.66, p <.01); it confirms the previous ANOVA by showing that there is no significant difference between the groups ($F_{2,1051}$ =1.53, p =.22) despite the observable difference in means in figure 2; however there is a significant interaction between participants within the groups ($F_{194,1051}$ =2.11, p <.01). This is further demonstrated when a Univariate ANOVA is performed to assess the variance between the participants with separate groups ($F_{97,1247}$ =3.44, p <.01, partial η^2 =0.21).

Insert Figure 2 here

As with the experimental conditions, individual effect sizes where calculated using the same procedures as above with the addition of Hedges and Olkin's correction for *d* statistic bias that is recommended when there is less than 10 samples in each group (Hedges and Olkin, 1985).

The mean difference in formative assessment between Control and Long was 0.34 (95% confidence interval -21.72 to 22.39, p =.40) and Control and Short was 0.65 (90% confidence interval -21.02 to 22.32, p =.33). The magnitude of this effect for each comparison was small (effect size 0.49: -0.39 to 1.37) and (effect size 0.57: -0.28 to 1.42), respectively. The probability (% chances) that the true population effect is beneficial/ trivial/ harmful is 45.9/50.6/3.5 and 52.1/45.1/2.7:

therefore the interventions are possibly beneficial and most notably very unlikely to be harmful.

Accesses

Throughout the duration of the testing periods the accesses to the control site and amount of times each of the videos was played within each of the video sites was monitored and recorded. The control website was accessed 365 times in total, the five long videos where viewed 453 times in total (1.24 times more than the control) and the twenty-five short videos where viewed 958 times (2.62 times more than the control and 2.11 times more than the long videos). As the students could view these videos in groups it is impossible to correlate individual accesses with formative scores.

Academic Performance

In conjunction with their individual formative marks for each of the three conditions and their summative mark from the rehabilitation module, summative data from the end of the students first year practical examinations was available that enabled a Spearman's Rho to be performed to identify any trends between the data sets.

The results of the analysis show that there is a strong positive correlation between the average mark from the student's first year practical examinations and their final rehabilitation mark (0.53, $p < .01$) and between their formative marks obtained during the Short and Long video conditions and their final rehabilitation mark (0.28, $p < .05$ and 0.29, $p < .01$, respectively).

Discussion

The differences between experimental conditions did not show any statistically significant results for the group or the individual analysis, however the use of effect size statistics which enables the researcher to 'move towards a more generally interpretable, quantitative description of the size of an effect' (Fritz et al., 2012) demonstrates a small effect size when both the experimental groups were compared to the control group. The real life relevance of this was an increased mean score over the control group, whilst this was only a modest increase in the mean score the additional couple of marks for a group or an individual could mean the difference between pass and fail or the attainment of a higher classification boundary. The magnitude-based inferences indicate the most important findings from this study, showing that both of the video groups are almost certainly not harmful to the participants. Whilst the probabilities for a beneficial or trivial effect are both within the central quartiles, with beneficial being marginally greater than trivial, it is clear that videos are to some degree beneficial when students are working in groups.

A comparison of the two experimental groups demonstrate a substantially reduced mean difference and an insubstantial effect size, suggesting the different

delivery durations, infringement of the redundancy principle and production value made little difference to the scores achieved by the groups.

When the findings for individuals are interpreted the two-way factorial ANOVA identifies that the scores achieved by individuals are significantly different from each other demonstrating that individual data can be extrapolated from the experimental group design. Furthermore there is a significant interaction between the groups, as just over one-fifth of the variance is explained by the combined effect of the video groups.

The effect sizes are classified as small, are approximately twice as large for individuals than groups (with a corresponding increase in confidence intervals). This partly reflects the small scale of the study. The magnitude-based inferences for individuals follow a similar pattern to the groups with the beneficial and trivial probabilities being almost equal and the probability that the intervention will have a harmful effect being exceedingly small. As a result the confidence intervals illustrate the extent of the effect on the scores of the individuals with a dramatic effect. Within the cohorts there are clear differences in the effect of videos in a beneficial or harmful way, however the majority of the time this is beneficial with the effect being the equivalent of an entire classification boundary for some students (10% boundaries). In addition the findings of the Spearman's rho indicate that the marks the students obtained individually when in the short or the long video group is significantly correlated with the marks they obtained on an individual basis in the final summative rehabilitation examination, whilst the marks obtained when they experienced the control group were not. It is not possible to claim that the videos had a direct influence due to the assumption that different levels of preparation undertaken in the run up to formative assessments opposed to summative, however it demonstrates that they were working at a level that is similar to their academic performance in the examination making the feedback and advice more relevant and beneficial.

As a result of these findings it is possible to agree with the generalised conclusions from Chen, (2011) McNulty et al. (2009a) and Zhang et al. (2006) that e-learning can improve traditional teaching methods, with a caveat that it may not be effective for the entire cohort. The magnitude of the improvement can vary considerably across groups and individuals, and whilst the interventions did not necessarily promote learning efficiency or effectiveness consistently in agreement with Chen et al. (2011) and Kala et al. (2010) their adoption or integration will probably be of benefit for a large proportion of the cohort. The most noteworthy finding of this study is that the probability of the use of videos being harmful to a group or an individual is exceedingly small and although this does not provide conclusive evidence of the effectiveness for teaching clinical skills that Bloomfield et al. (2010) are seeking, it should encourage educators to consider adopting the use of videos to teach clinical skills. This is particularly relevant when you consider how important the role of observational learning still

is within education to this day (Gog et al., 2008). Video's ensure that the viewing of flawless and error free movements performed by experts can be repeated and analysed an unlimited number of times embedding and reinforcing the movement with no cognitive variation. The ability to pause and work through a complex movement one frame at a time provides the learner with an incredibly powerful tool, a mechanism that can transform the passive design and promote constructivist learning.

Limitations

The assessment of psychomotor skills is not as objective as it is for other domains, whilst the reliability of assessment within this study was reasonable it could be the subjectivity of this element is an area that would benefit from further research for the students and the examiners to ensure standards and marks achieved/given are as reliable as possible. The scale of this exploratory study was small with three conditions (short video, long video and control) meaning it was not sufficiently powered to detect small effects. A larger scale study could be undertaken to establish the effectiveness of video use in this context.

Conclusion

The role of instructional videos within traditional learning should be further encouraged; although the current study could not establish a conclusive evidence-base for their inclusion the effects observed are potentially substantial for some students given the real world application of the small effect size on grade boundaries. The study has established that instructional videos are very unlikely to be harmful to a students learning and may have other benefits that the study has been unable to quantify such as flexibility of learning (any time or place with an internet connection and the ability to be repeated instantly) and consistency of delivery that could aid the acquisition of cognitive, affective and psychomotor elements within each taxonomy further. Future research into the use of instructional videos should be undertaken on a larger scale, with a less complicated research design to improve power, aim to include a strict method of objectifying each taxonomy and attempt to control and monitor the usage of content further.

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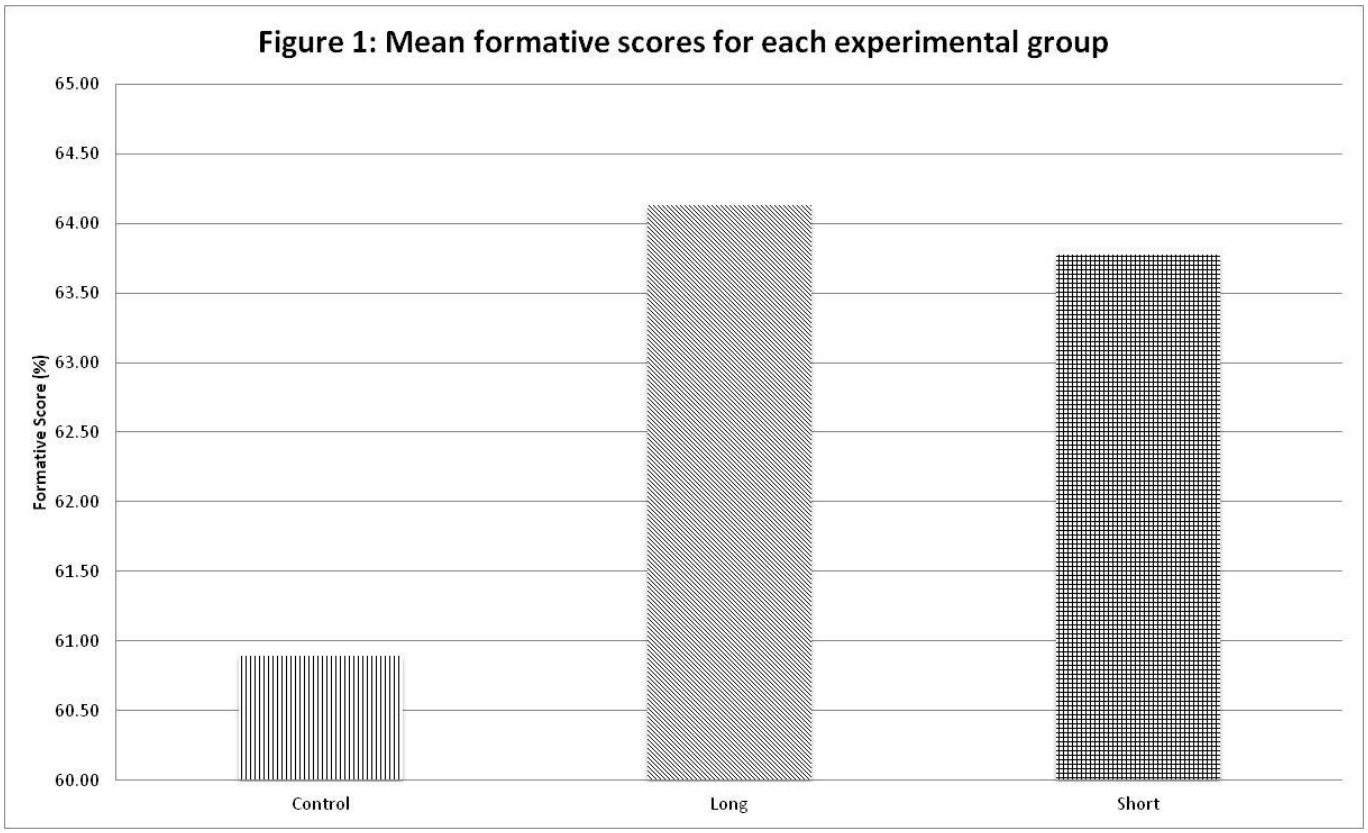
Table 1: Crossover design

Phase	Group A	Group B	Group C
1	Control	Long	Short
2	Long	Short	Control
3	Short	Control	Long



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