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The influence of professional expertise and task complexity upon the potency of the contextual interference effect

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Abstract

The contextual interference (CI) effect has been investigated through practice schedule manipulations within both basic and applied studies. Despite extensive research activity there is little conclusive evidence regarding the optimal practice structure of real world manipulative tasks in professional training settings. The present study therefore assessed the efficacy of practising simple and complex knot-tying skills in professional fire-fighters training. Forty-eight participants were quasi-randomly assigned to various practice schedules along the CI continuum. Twenty-four participants were students selected for their novice knot-tying capabilities and 24 were experienced fire-fighters who were more 'experienced knot-tiers'. They were assessed for skill acquisition, retention and transfer effects having practiced tying knots classified as simple or complex. Surprisingly, high levels of CI scheduling enhance learning for novices even when practising a complex task. The findings also revealed that CI benefits are most apparent as learners engage in tasks high in transfer distality. In conclusion, complexity and experience are mediating factors influencing the potency of the CI training effect in real-world settings.

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1. Introduction

The influence of contextual interference (CI) in motor learning research has evolved over 20 years since early laboratory based studies demonstrated the CI effect (e.g. Battig, 1966, 1979; Shea & Morgan, 1979). To date there is little research that evaluates the application of CI manipulations within professional development environments out-with that of sport. However, some applied studies are beginning to emerge (Hanlon, 1996; Knock, Ballard, Robin, & Schmidt, 2000; Schneider, Healy, & Bourne, 2002) that may help bridge the gap between lab-based research and vocational and professional practice. The present research utilised trained fire-fighters and a non-trained control group and assessed their capability to learn to tie a variety of knots. Knot-tying skill is paramount in the fire-fighters profession and to date the training structure for this skill has not been evaluated within a controlled practice framework. Given that the potential benefits of CI manipulations have arguably yet to be fully realised within real world training environments, the present paper adds to the professional understanding of the CI phenomenon in real-world settings.

An overview of CI research typically reveals that acquisition performance is improved with repetitive, blocked task practice, while retention and transfer performance benefit from random practice scheduling (Brady, 1998). While these findings are generally accepted, factors such as task complexity, participant skill level, and environmental conditions also seem to influence the strength of the CI effect (for a review see Wulf & Shea, 2002). For example, some research has failed to reveal any benefits of CI (e.g. French, Rink, & Werner, 1990; Sears & Husak, 1987 (as cited in Brady, 1998); Chamberlin et al., 1991 (as cited in Brady, 1998)) whilst other research studies supported the adoption of high CI manipulations (e.g. Hall, Domingues, & Cavazos, 1994; Hebert, Landin, & Solmon, 1996; Wrisberg & Liu, 1991). These varied results could be interpreted as a result of methodological nuances (e.g., task and subject characteristics) and might also represent a degree of 'diminishing return' (Brady, 1998). In other words, the potential benefits of CI may decline from an optimum level as a result of the interaction of several factors. Brady (1998) has suggested that some of the other important factors influencing the CI effect include; amount of practice (Shea, Kohl, & Indermill, 1990), cognitive effort (Smith, 1997), intrinsic interest (Lee & White, 1990), experience (Shea et al., 1990), motivational/attentional process (Lee & White, 1990), task complexity (Hebert et al., 1996; Wulf, Herger, & Shea, 1999), and trait anxiety/self efficacy (Shewokis, Krane, Snow, & Greenleaf, 1995). While many of these factors will undoubtedly be of interest within future research, the present study will focus upon the expertise and complexity inter-relationship.

Although high levels of CI can impair skill acquisition performance, retention and transfer effects also require close scrutiny. Salas and Canon-Bowers (2001) acknowledged that successful retention and transfer of skills are the most important indicators of training effectiveness and expertise. Retention tests within motor learning are administered by assessing the performance of a skill some time following the initial practice period. The level of performance during the retention test and the duration of the post-practice delay both indicate the extent of skill retention. Skill retention is particularly important within public services such as the fire brigade, police and military where it would be futile to perform expertly on the training ground and not be able to retain important skills at a later date.

A number of researchers suggest that skill retention effects may not be as informative as skill transferability. For example, Shewokis and Snow (1997) suggested that transfer effects are consistently more robust than retention effects within CI research and therefore transfer conditions should be regarded as more reliable indicators of CI benefits (see also Brady, 1998). Transfer tests examine the 'adaptability of performance changes' related to learning (Magill, 1998). Smith and Rudisill (1993) have considered 'transfer distality' or near-and-far transfer (Schmidt & Wrisberg, 2000) within their research. Transfer distality reflects the extent to which a transfer task (or test) is similar to the task practised within the acquisition period. While 'near transfer' requires a task to be performed that is similar to that acquired in the learning environment, 'far transfer' would involve a task or performance situation that would be very different from the learned task. Transfer distality is necessary within fire-fighting to react appropriately under extreme and novel conditions. For example in a burning building where conditions can change unpredictably, the Fire Brigade training literature [1] emphasises the understanding that 'every fire (and rescue) situation is different' (Scottish Fire Training School Manual, 2002). Brady's (1979) research investigating the benefits of dry land training for scuba divers exemplified this requirement for far transfer within high-risk sports, and is one of a few studies which can be extended to high-risk professions.

With such practical and professional concerns in mind current folklore suggestions involving large amounts of simple-blocked practice in the armed and emergency services (such as gun assembly and dry gun drills in the military) cannot be supported by the guidelines that have emerged from the CI literature. Training methods that are underpinned by CI scheduling could serve to enhance training effectiveness and understanding thereby enhancing the training of professionals. Beyond appropriate practice schedules we also need to recognise dominant variables that mediate the benefits of CI, and secondly, how these variables interact in relation to the transfer distality principle. The two characteristics that have received most attention to date are expertise and complexity (Guadagnoli & Lee, 2004; Wulf & Shea, 2002), although they have typically been studied in isolation of each other.

The adoption of a knot-tying task within the present study allowed us to examine effects with continuous (long duration) responses as might be expected in real-world scenarios. This approach is motivated by Smith's (1997) contention that CI manipulations have tended to be focused on memory driven issues that are more easily targeted by short duration responses. The demand for capable knot-tying skill within

[1] Furthermore, competence based training through occupational and educational systems (i.e., National Vocational Qualifications in the UK) are still predominantly focused upon the acquisition of skills competence, with little reference to retention or transfer issues.

the professional based domain of fire-fighting also determined our transfer tests. The first transfer test which involved tying knots blindfolded reflected a concern that fire-fighters have to tie knots within confined and smoke-filled/dark locations. The second transfer test assessed the ability to tie novel knots to help fire-fighters adapt to the needs of any incident (e.g. where secure tie-points may be restricted). Therefore, it seemed appropriate for the participants to be able to demonstrate whether they could tie some novel knots which they had not previously practised. The adoption of both transfer tests meant increased distality for the learners from transfer test 1 to transfer test 2. The blindfolded knots were the same as the ones practised in acquisition, but performed without vision (near-transfer). The second transfer test represented far transfer as the participants had to perform a different sequence of moves to complete the knots.

We propose that discrepancies between research findings (French et al., 1990; Hebert et al., 1996; Sears & Husak, 1987; Wrisberg & Liu, 1991) have arisen through the interaction of multiple variables in applied (and some laboratory) settings and that these variables influence the CI effect in a multi-faceted manner. The interaction of task complexity and expertise within CI conditions was a primary focus within the present research. Practising skills high in complexity may amplify the cognitive and physical demands created by high levels of CI (Albaret & Thon, 1998). Hence, practising more complex tasks under high-interference conditions may prove too difficult for early learners to elicit CI benefits (Magill & Hall, 1990). Alternatively, more expert individuals may not find simple skills challenging enough even under random practice schedules to generate a clear CI benefit. As such, expertise and task complexity characteristics require closer scrutiny.

Therefore to examine the potency of the CI effect in applied practice settings, three hypotheses are presented. In the absence of prior research that has investigated several levels of task complexity and subject experience interactively, it was assumed that a simple linear effect on learning may exist for each factor in isolation. The benefits from CI within the present study will therefore be assessed by improved retention performance or, more importantly, increased transfer distality. So, (1) in terms of the interaction of complexity and experience within the real-world setting, it is predicted that the benefits of high CI will become more apparent with increasing transfer distality. (2) The experienced learners should benefit more than novices from high levels of CI scheduling (Guadagnoli & Lee, 2004; Magill & Hall, 1990). (3) Finally, as task complexity increases within the present study (simple vs. complex knots) the relative benefit from increasing levels of CI should decrease (Albaret & Thon, 1998; Guadagnoli & Lee, 2004; Wulf & Shea, 2002).

2. Method

2.1. Participants

The participants were 24 sports science students (age = 21–32) and 24 qualified fire-fighters (age = 23–49) from Rosyth Fire Station. While the students had no experience in knot-tying skills, the fire-fighters had achieved competence standards and expertise during their basic fire-fighting training and previous 'operational line-rescue' status. The fire-fighters had at least 2 years experience in rope work and knot-tying, but should not be considered 'expert knot-tiers' due to their broad working role (i.e., they are only required to practice tying of occupationally relevant knots). Therefore the students were subsequently termed 'novice knot-tiers' and the fire-fighters were termed 'experienced knot-tiers'. All participants gave informed consent to participate.

2.2. Task and equipment

A group of experienced knot-tiers (who did not participate in the experiment) evaluated 10 different knots in terms of complexity. The acquisition task involved the tying of six selected knots (three 'simple' knots, three 'complex' knots) to a set standard as quickly as possible. The simple knots chosen were the 'figure of 8', the 'round turn-two-half hitches' and the 'highwayman's hitch'. The complex knots were the 'fisherman's knot', the 'running bowline' and the 'double-figure of 8' (Fig. 1). The criteria for completed knots involved a subjective assessment by an independent, experienced knot-tier. Each knot had to be recognisable, have a 30 cm tail and have the capability to carry out the function for which it is employed. There were also two transfer conditions which have been discussed. In the first transfer test, all participants had to tie the knots previously learned, blindfolded. The second transfer test

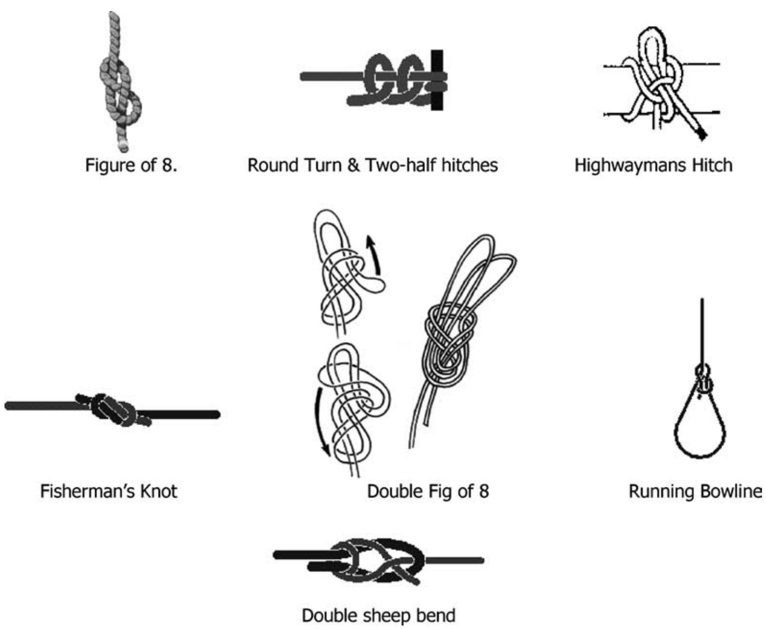

Fig. 1. Simple, complex and transfer test knots.

involved tying a novel knot, not used within the acquisition period (rated at 'medium complexity'). The novel knot was the 'double sheep-bend'.

The equipment required for the experiment included a climbing line of 12 mm diameter, made of natural fibres. Two bars were required as fixings for the knots. The first bar was fixed at hip height, and was used with the utilisation of a weight lifting bar and mobile bar stand. The second bar was fixed at head height and constructed using gym scaffolding. The first bar was necessary to tie the 'round turn-two-half hitches' knot. The second bar was used in conjunction with the 'highwayman's hitch' and the 'running bowline' knots. The other three knots required no fixing. Two 'Cronus Cum/Time 601X Stopwatches' were utilised as timers during the experiment.

2.3. Pre-test

An initial test involved tying all six knots which established a baseline of knot-tying abilities amongst the two groups of participants. The total time to tie the three simple knots and the three complex knots, were recorded. The novice and experienced groups were then quasi-randomly assigned on ability level into six groups of eight participants. Each of the six groups were then assigned to the experimental conditions of low CI, moderate CI or high CI. The low CI group received blocked practice; the moderate CI group had random-blocked practice and the high CI group had random practice.

2.4. Procedure

The pre-test took place four days prior to the practice sessions. At this time, participants were given a brief explanation of the acquisition process, a demonstration and familiarisation of all six knots. The initial familiarisation consisted of four attempts of each knot in a blocked fashion to allow the novice participants the opportunity to complete each knot during acquisition. The experts were also required to tie each knot four times. Practice sessions for all groups involved tying the appropriate knots twice a day for eight days (see Appendix A). Due to the fire-fighters shift-patterns of four days-on, then four days-off, the student group also followed the same schedule. Each participant performed 24 trials per day in two practice sessions, in accordance with the respective practice schedule assignment. Participants assigned to the blocked practice schedule tied each knot four times blocked. The first practice session involved tying three simple knots four times. The second session involved tying three complex knots four times. Participants assigned to the random-blocked practice schedule tied each knot twice, rather than four times in each session. Therefore, both the first and second practice sessions involved tying all eight knots twice in blocked fashion. Finally, the random practice groups were required to tie each knot twice, but in a highly random order. The acquisition tests were conducted daily during the practice sessions.

For each acquisition period the time to completion of each knot tied was recorded. For the blocked group, the mean of four knots was calculated; for the random-blocked group, the mean of two knots, and for the random group singular knots times were noted by the experimenter. These times were then grouped together as either simple or complex knot times. Twenty-five percent of timings were measured by two referees to ensure inter-tester reliability (objectivity). All times (measured to the nearest second) clarified with an inter-observer agreement (IOA) of 100% (Thomas & Nelson, 2001).

2.5. Post-test

Four days after the final acquisition test was completed, the retention and transfer tests were conducted. The retention test mirrored the pre-test in that the total times for all three simple knots and for the three complex knots were recorded. To prevent an order effect during the transfer test, half of each group began the transfer test with the novel knot, and the other half began the transfer test with the tieing of the blindfold knots. In relation to transfer distality, the blindfold knots were considered closer to the acquisition task, and the novel knot more distant.

2.6. Data analysis

The total times to tie the three knots at pre-test were submitted to a 2 (Experience) × 3 (CI level) × 2 (Knot complexity) analysis of variance with repeated measures on the last factor. For the acquisition data, total knot-tieing times were submitted to a 2 (Experience) × 3 (CI level) × 8 (Acquisition block) × 2 (Knot complexity) analysis of variance with repeated measures on the last two factors. The analysis that was used for the pre-test data was also applied to the retention phase data. Finally, the knot-tieing times in the transfer tests were submitted to a 2 (Experience) × 3 (CI level) × 3 (Transfer condition) analysis of variance with repeated measures on the final factor. In order to correct for sphericity violations, F values were corrected with Huynh–Feldt adjustments where necessary and due to the low sample size, effect size statistics are also reported [2] (Field, 2000). Post hoc analyses of main effects and interactions were carried out with pairwise comparisons, corrected with the Bonferroni method to control for inflated Type 1 error.

3. Results

3.1. Pre-test

The analysis of variance indicated main effects for Experience, $F(1,42) = 38.12$, $p < 0.001$, partial $\eta^2 = 0.48$, and Knot Complexity, $F(1,42) = 264.86$, $p < 0.001$, partial $\eta^2 = 0.86$. An interaction between Experience and Knot Complexity,

[2] It is acknowledged that the low sample size within the study ($n = 8$ per group) compromises the power of any statistics reported. Due to practical limitations of data collection it was not possible to recruit additional subjects at the time of testing. The reader is reminded to consider this limitation when interpreting the findings.

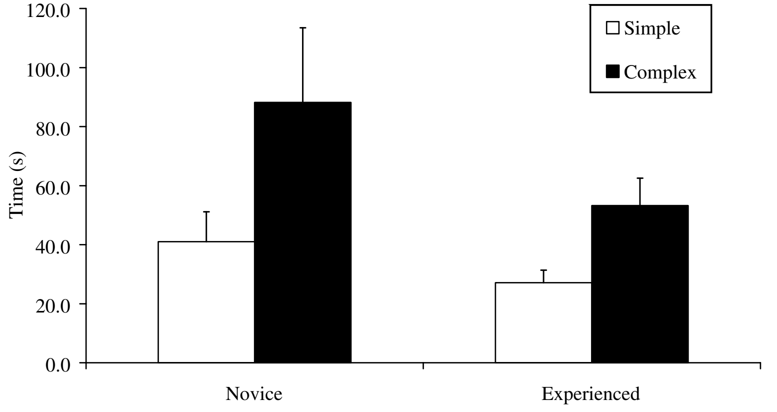

Fig. 2. Interaction of expertise and knot complexity for mean knot times during the pre-test (data collapsed across CI levels).

$F(1,42) = 21.83$, $p < 0.001$, partial $\eta^2 = 0.34$, was attributable to the novices finding the complex knot more difficult in relation to the experienced participants (see Fig. 2). The quasi-random assignment of groups meant that the CI level main effect or interactions were not statistically significant, [3] $p > 0.05$.

3.2. Acquisition

Each group showed an improvement (reduction) in knot-tieing times over the training period. There were main effects for Acquisition Block, $F(4.12, 173.07) = 118.65$, $p < 0.001$, partial $\eta^2 = 0.74$, as well as the predicted effects for Experience and Knot Complexity (p's < 0.001). Pairwise comparisons revealed differences particularly between the early acquisition blocks (p's < 0.001) with knot-tieing times plateauing later in acquisition (e.g., comparisons between 4 and 5, 5 and 6, 7 and 8 were not significantly different). Perhaps surprisingly there was no main effect for CI level ($p > 0.05$, partial $\eta^2 = 0.01$) However, there was an interaction between CI level and Acquisition Block, $F(8.24, 173.07) = 2.30$, $p < 0.03$, partial $\eta^2 = 0.10$. Fig. 3a and b reveals this interaction with the high CI groups performing poorly early in learning, however during later acquisition blocks this trend was reversed and high CI performance was generally better than the low and moderate CI trained groups.

[3] It should be pointed out that due to a comparatively high amount of variance within the novice groups compared to the experienced groups, Levene's test for Homogeneity of Variance indicated a significant difference between ability groups ($p < 0.05$). As both natural log and square root transformations of the data set did not stabilise the variances, we decided to use the original data set within the analysis. Therefore, we acknowledge that this violation could compromise the accuracy of the F-ratio for ability (Field, 2000) but argue that the difference in variance might be expected given the differences in ability required within the study.

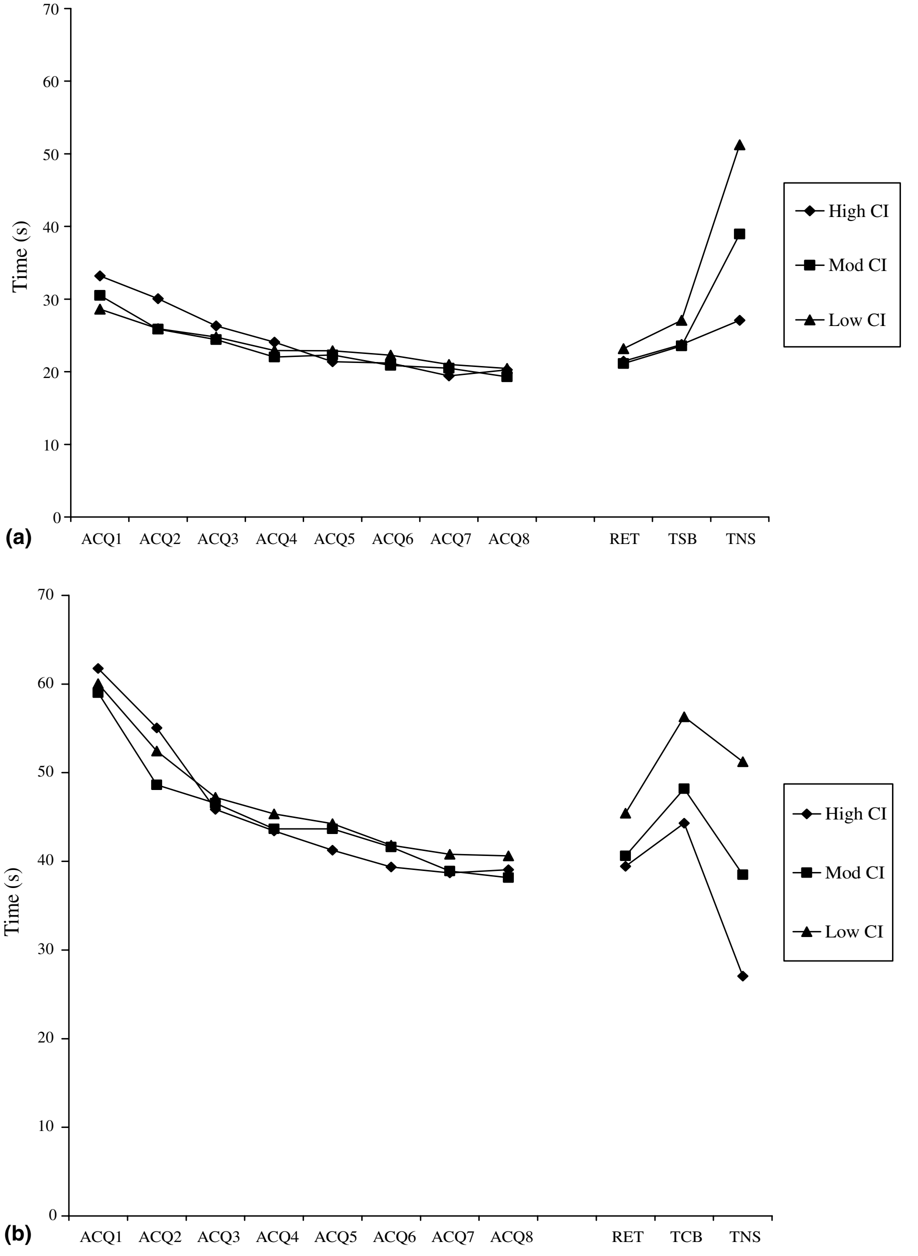

Fig. 3. (a) Mean times to complete knot-tying task for simple knot groups (data collapsed across experience levels). High CI: high contextual interference, Mod CI: moderate contextual interference, Low CI: low contextual interference. (b) Mean times to complete knot-tying task for complex knot groups (data collapsed across experience levels). High CI: high contextual interference, Mod CI: moderate contextual interference, Low CI: low contextual interference.

3.3. Retention test

When comparing performance across the groups in the retention block there were main effects for Experience, $F(1,42) = 40.22$, $p < 0.001$, partial $\eta^2 = 0.49$, and Knot Complexity, $F(1,42) = 763.43$, $p < 0.001$, partial $\eta^2 = 0.95$. Fig. 3a and b shows that the complex knot groups perform least well during the retention test and the best times came from the simple knot groups. The retention performance of all six groups was generally maintained in relation to their respective final acquisition block. The impressive retention performance for all groups suggests a lack of obvious differential benefits from the various permutations of CI level.

3.4. Transfer tests

There were three transfer conditions for each group, simple knots blindfolded (TSB), complex knots blindfolded (TCB) and also a novel set of knots in normal sighted conditions (TNS). The latter of these transfer tests was considered most different from the acquisition task in terms of transfer distality as none of the groups had any experience of these knots prior to the test. There were main effects for Experience, $F(1,42) = 59.05$, $p < 0.001$, partial $\eta^2 = 0.49$, for CI level, $F(2,42) = 5.49$, $p < 0.01$, partial $\eta^2 = 0.21$, and also for Transfer conditions, $F(1.57,66.07) = 45.34$, $p < 0.001$, partial $\eta^2 = 0.52$. Pairwise comparisons revealed that the mean transfer times for the high CI groups (31.7 ± 12 s) were significantly lower than for the low CI groups (48.9 ± 12 s), but not significantly different than the moderate CI groups (36.9 ± 12 s). There was also a significant interaction between Transfer condition and CI level, $F(3.15,66.07) = 2.71$, $p < 0.05$, partial $\eta^2 = 0.11$. From Fig. 4a–c, it seems that the CI groups performed equally as well for the simple, blindfolded condition but the high CI groups had better times in the other two transfer conditions. Furthermore, a significant three-way interaction between Transfer condition, CI level and Ability, $F(3.15,66.07) = 3.66$, $p < 0.02$, indicates that the novice groups reacted differently to the CI training in comparison to the experienced groups.

Novice transfer tests. Within the novice groups, the best performance occurred when blindfolded simple knots were tied, regardless of their CI level during training (Fig. 4a). In comparison, for the blindfolded complex knot task, there was a trend that high CI participants tended to be quicker than the low CI group (Fig. 4b). However, this trend was not significant. Finally in the novel knot condition, the high CI group again performed better than the low CI group ($p < 0.01$) and showed a trend towards greater transfer over and above the moderate CI group (Fig. 4c).

Expert transfer tests. For the expert groups there were few clear benefits between one type of CI training on another. Similar to the novice groups, the high CI group seemed to perform better with the blindfolded complex knot (Fig. 4b), although once more this trend did not reach significance. However, pairwise comparisons revealed some clear differences between the transfer conditions. Transfer performance for the novel knot was worse than that of the blindfolded simple knot, which in turn was better than the blindfolded complex knot. When comparing across all three transfer

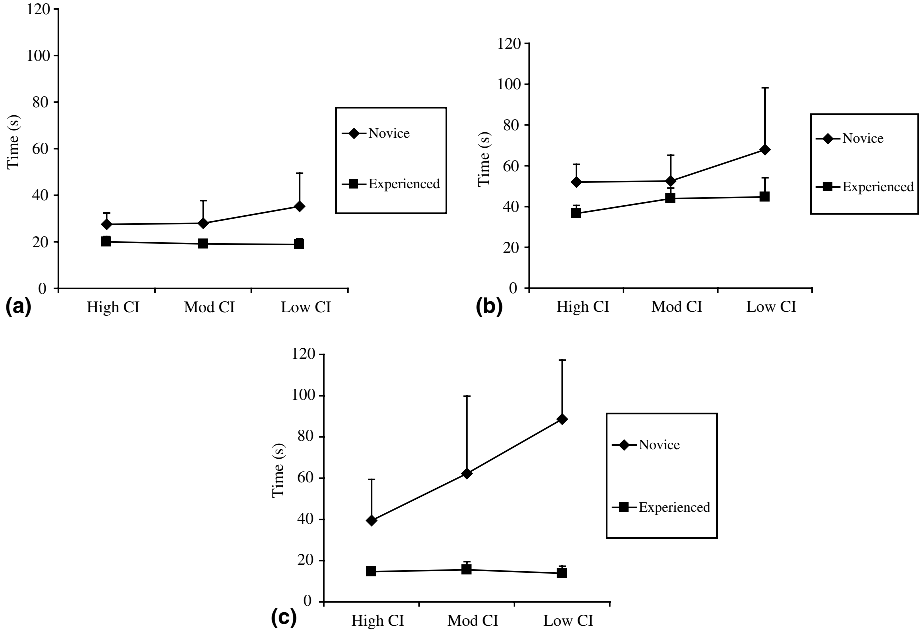

Fig. 4. (a) Mean times to complete near transfer task (simple knot, blindfolded) for novice and experienced CI groups. (b) Mean times to complete near transfer task (complex knot, blindfolded) for novice and experienced CI groups. (c) Mean times to complete far transfer task (novel knot, sighted) for novice and experienced CI groups.

conditions, it is clear that the experts performance in transfer conditions was better than that of the novices particularly as transfer distality increased.

4. Discussion

It was the purpose of the present study to investigate the applied interactions and theoretical relationships between expertise, complexity, CI effect and transfer distality in a real world and professional setting. Our research assessed these variables within a professional fire-fighting task. This approach supports Salas and Canon-Bowers (2001) recognition that enhancing transfer and retention factors in various occupational settings such as military, emergency service and industrial settings is key to promoting effective training. In relation to the main experimental hypothesis, the present retention and transfer data indicated that as both novice and expert learners engaged in tasks of increasing transfer distality, the benefits of higher CI practice schedules were identified more readily. The benefits of high CI increased exponentially and to higher significance as transfer task distality increased (see Figs. 3a, b and 4a–c). This finding supports Shewokis and Snow's (1997) suggestion that transfer effects are consistently more robust than retention effects within CI research. As skill transferability is more informative than acquisition or retention results, the transfer condition should be regarded as the more reliable of CI benefits within 'real-world' settings. It is important to acknowledge however that a period of 'learning symbiosis' from alternative learning experiences is more likely to occur as both transfer distality and experience increase. Within the present research, the far-transfer task for the experienced groups (see Fig. 4c) may not have proven as difficult as expected partly because ongoing training and exposure to real life conditions provide a constant source of alternative transfer exposure. This was clarified by the fire-fighters who acknowledged that the transfer test 'novel' knot was similar to a knot that the novice groups had not encountered. It still however remains difficult to refute that the general benefits of high CI levels are enhanced as transfer distality increases.

Contrary to our expectations, the present data indicated that complex knots were not too difficult for learners to benefit from CI practice as indicated in previous research (Albaret & Thon, 1998; Wulf & Shea, 2002). Results for the novice groups highlighted the benefits of high CI in both simple and complex tasks along the transfer distality continuum. In contrast, the experienced groups seemed to require a degree of task complexity before the benefits of high CI were acknowledged. These data are also contrary to the findings of Guadagnoli and Lee (2004) and Hall et al. (1994) who showed that as the learner's expertise increases, the benefits of higher levels of CI should materialise. The novice group in fact benefited more from the high CI levels than the expert group in relation to the second transfer test of 'novel' knot-tying. The trends in these data suggest that high CI improves retention for both novice and experienced learners although these comparisons did not reach statistical significance.

The adoption of the null hypothesis in relation to expertise and complexity help offer an alternative explanation to the CI effect from previous literature. Instead of understanding whether the CI effect was beneficial in either simple or complex tasks, or whether the high CI level was more beneficial to novices or experts, the present findings suggest that the benefits of a high CI practice scheduling can be both facilitative and debilitative. It is only *when* you measure the CI effect across the transfer distality continuum can you identify where the high CI level facilitates performance most. This finding suggests the potential need for sports and occupational professions (that rely on high transfer and retention capabilities) to adopt high CI practice, even though the results may be detrimental to the training ground performance. However, it should be acknowledged from the present findings (see Fig. 3a and b) that the detriment to acquisition performance was also not as great as previous laboratory findings would suggest.

When these results are collated alongside previous research the suggestion is that expertise, task complexity and distality interact and that the benefits of the applied CI level are context specific especially in relation to retention and transfer needs. We propose that primarily, there is a need to evaluate expertise levels and task demands prior to and during the setting of CI levels within the experimental design. For example, when tying knots in a real-world incident, increased obstacles, difficulties and anxiety emerge within the fire and rescue environment. The interaction of numerous variables therefore demands a high transfer capability, and in light of the present data, would be difficult to identify solely from the acquisition and retention phases of learning. Therefore, the present study would indicate the need for preliminary performance and task analysis based on transfer distality to determine if the CI effect is indeed relevant for the task in hand.

For novices, high levels of CI seemed to enhance learning whereas experienced performers may require the destabilisation of performance through alternative sources rather than practice structure manipulation alone. Such activities may be set up by the manipulation of the practice structure in line with the many different combinations of tasks observed within the professional domain under scrutiny. These tasks could also involve additional problem solving activities out-with the primary task being trained. This additional manipulation may be necessary in order to 'promote additional cognitive effort' (Lee, Swinnen, & Serrien, 1994) or 'require the learner to engage in additional information-processing activities that are critical for test performance' (Schmidt & Bjork, 1992). As such, theoretical considerations would then focus on longitudinal analysis of expertise and the complexity of inter-relationships along with an ability to analyse performance stability within a CI manipulation.

The adoption of high CI levels support Guadagnoli and Lee's (2004) recognition that finding appropriate 'challenge points' is important due to 'overall efficiency of processing information being dependent on task difficulty that is determined by the ability of the performer, the complexity of the task, and the conditions of practice'. The present research proposes that there may be a further myriad of destabilising factors that impinge on an individuals potential, and can only be identified through further real-world experimental tasks. For example, it is necessary to identify how interference occurs in relation to training factors such as periodisation of training and what is being destabilised. Moreover, we need to know if the adopted levels of destabilisation are appropriate and whether the destabilised challenge point is appropriate to facilitate the transfer task. It should be recognised that the interpretation of the present findings also suggest the dominance of a level of automaticity and learning effect over and above the CI effect (expert–simple retention knots). As such, to ensure a suitable challenge point will occur, alternative constraints out-with knot-tying scheduling should be pre-considered prior to the construction of meaningful transfer designs.

5. Conclusion

The results of this study suggested that a unilaterally determined level of CI or a linear approach to understanding the influence of task complexity and level of expertise in a real-world setting is inappropriate. The present findings indicated that there is a need to understand inter-relationships between expertise, complexity, task needs, CI levels and various other variables before a particular CI level can be advocated as the 'most beneficial'. Secondly, support was found for the CI effect being more effective as the fire-fighters tied knots further along the retention-transfer distality continuum. Together, both these factors indicate that the 'most beneficial' organisation of practice will be indicated *when* the CI effect appears most facilitative across the transfer distality continuum, rather than perceiving *whether* the CI effect is beneficial for a level of expertise or task complexity from a one-dimensional perspective. Overall, these findings indicate a need to conduct a preliminary task and performance analysis before appropriate challenge points can be identified and optimised for suitable skill retention and transfer.

Appendix A

Practice schedule: conducted twice per day for each individual (am and pm).

	High CI
Day 1–4	12 random (2 of each)
Day 5–8	Off duty
Day 9–12	12 random (2 of each)
Day 13–16	Off duty
Day 17	Retention and transfer tests

	Moderate CI
Day 1–4	12 knots in blocks of 2
Day 5–8	Off duty
Day 9–12	12 knots in blocks of 2
Day 13–16	Off duty
Day 17	Retention and transfer tests

	Low CI
Day 1–4	Simple knots in blocks of 4 (am) Complex knots in blocks of 4 (pm)
Day 5–8	Off duty
Day 9–12	Simple knots in blocks of 4 (am) Complex knots in blocks of 4 (pm)
Day 13–16	Off duty
Day 17	Retention and transfer tests

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