Meta-Analysis of the Minimalist Training Model

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ABSTRACT

This article reviews research on the Minimalist instructional design model, a learner-centred approach to the design of instructional materials such as computer program manuals or on-line help. Studies in this paradigm have typically compared minimalist materials against traditional “system-centred” materials. Additionally, some studies have investigated the effects of specific minimalist design heuristics. However, small samples in many original studies have meant effect size estimates are imprecise. Meta-analytic methods were applied to 13 experimental effect sizes comparing the minimalist and system-centred approaches, and 6 effects investigating the effects of specific minimalist heuristics (“support error recognition and recovery” and “slash the verbiage”). The overall mean effect on learning in favour of the minimalist approach was large (d = 1.12), broadly supporting the minimalist approach compared to system-centred designs. The mean effect for tests of the “support error recognition and recovery” principle was moderate (d = 0.59), and the mean effect for tests of the “slash the verbiage” principle was large (d = 0.89). These results indicate the application of minimalist design principles to self-study manuals for learning to use computer programmes is associated with more effective learning. By applying these principles, designers of such manuals can assist learners, as well as gaining a competitive edge. (Contains 3 tables)

The complexity of most computer programs, and more generally, information and communication technologies (ICTs) (e.g. fax machines, personal digital assistants, gaming consoles), has generally required that they be sold with some form of documentation. Typically, such documentation has been *system-centred* – that is, focussed on providing a comprehensive account of a technology's functions and limitations, and emphasising set sequences of drill and practice, based on hierarchical decomposition and clear exposition of task structures (e.g. Gagne & Briggs, 1979). In the early 1980s, an alternative, user-centred approach to documentation design emerged, based on the work of John Carroll and colleagues at IBM. Qualitative and quantitative research programmes by Carroll and colleagues (e.g. Carroll, 1990, 1998; Carroll et al., 1987-1988), investigating the approaches to study used by learners under self-study conditions, revealed learners often did not feel obligated to stick to the instructional script provided for them by manuals. Instead, learners preferred to begin immediately on real tasks, rather than work through drill and practice routines for sub-tasks. They tended to be driven by their own learning goals, ignoring sections of manuals which appeared irrelevant to these goals. They also tended to rely on their own inferences from system prompts and unsystematic references to the manual, despite such inferences often leading to errors. Minimalist paradigm theorists (e.g. Carroll, 1998; Carroll & Rosson, 1987) have argued these learner behaviours and preferences flow directly from the human need for active sense-making while learning. Carroll (1998; p.29) notes that "[learners'] compelling orientation to meaningful activity continually undermines the motivation to spend time and effort "just" learning…the very dispositions that make people good sensemakers, are also causes for characteristic learner problems".

These findings led Carroll et al. (1987-1988) to develop a "minimalist" training model, consisting of a set of design principles for ICT instructional materials which accommodate and capitalize upon the above learning preferences and strategies. Van der Meij and Carroll (1997; p.21) summarised the following core minimalist design principles and heuristics as follows:

Principle 1: Choose an action-oriented approach
Heuristic 1.1: Provide an immediate opportunity to act.
Heuristic 1.2: Encourage and support exploration and innovation.
Heuristic 1.3: Respect the integrity of the user's activity.

Principle 2: Anchor the tool in the task domain.
Heuristic 2.1: Select or design instructional activities that are real tasks.
Heuristic 2.2: The components of the instruction should reflect the task structure.

Principle 3: Support error recognition and recovery.
Heuristic 3.1: Prevent mistakes whenever possible.
Heuristic 3.2: Provide error information when actions are error prone or when correction is difficult.
Heuristic 3.3: Provide error information that supports detection, diagnosis, and recovery.
Heuristic 3.4: Provide on-the-spot error information.

Principle 4: Support reading to do, study and locate.
Heuristic 4.1: Be brief, don't spell out everything (often referred to as "slash the verbiage").
Heuristic 4.2: Provide closure for chapters.

To date, there have been three distinct implementations of these minimalist principles and heuristics.

1) the *minimal manual* (e.g. Carroll et al., 1987-1988; Lazonder & van der Meij, 1993). Empirical studies of this implementation have compared learning from a standard, system-focussed, (often) off-the-shelf manual for a software programme or technology against a redesigned minimalist manual.
2) *training wheels* software (e.g. Carroll & Carrithers, 1984; Catrambone & Carroll, 1987), where system functions (e.g., for word processing) that novices do not typically need, but which often cause errors, are disabled. Empirical studies of this design typically require learners to use a minimal manual in conjunction with either a training wheels version or a full version of the software.
3) *genetic growing systems* software (e.g. Lohmann, 1993). This is a form of the training wheels approach in which learners begin with a very restricted range of programme functions, but with experience, can access more a greater range of functions. This use of scaffolding, like the training wheels approach, is intended to manage complexity of software and to support exploratory learning. Empirical studies of this design have compared genetic growing systems conditions with training provided by a professional trainer, as opposed to the use of conventional manuals as was the case for the minimal manuals approach.

A key feature of many studies of the minimalist paradigm is the influence of usability testing approaches, reflecting the genesis of this paradigm in ICT training. Specifically, many of the studies, although experimental in nature, have also used small numbers of participants and extended naturalistic training settings to explore the effect of minimalist interventions. While statistically significant differences between conditions favouring the minimalist materials have been found in many studies, the small sample sizes mean estimates of effect size (Cohen, 1988) are necessarily imprecise.

The present study uses meta-analysis (Lipsey & Wilson, 2001) to synthesize effects from the available experimental studies of the minimal manual and genetic growing systems, in order to provide a more accurate estimate of the magnitude of effect of minimalist training. The primary meta-analysis included studies which compared conventional, system-centred approaches to teaching and learning with a minimalist, learner-centred approach. (The training wheels studies were not included as these did not make such a comparison.) In these studies, the experimental condition materials were designed to incorporate all the minimalist principles described above. The second set of meta-analyses investigated tests of two specific minimalist principles: "support error recognition and recovery", and "support reading to do, study and locate". Meta-analysis of studies of the principles "anchor the tool in the task domain" and "choose an action-oriented approach" were not possible as multiple experimental investigations of the other principles could not be located.

Primary Meta-Analysis: Data Sources

Thirteen effects, representing the performance of 288 students, were located in 5 journal articles, 3 conference papers, 1 technical report, and 1 PhD thesis. The literature search was conducted with Psychinfo, ERIC and the Google and Google Scholar internet search engines using the keywords “minimal manual”, “minimalist”, and “training wheels” up to March 2006; searches using Science Citation Index of studies citing earlier studies; and examination of reference lists of individual articles and texts (e.g. Carroll, 1990; 1998). Studies were included if the article provided descriptive or inferential statistics for direct tests of learning (e.g. number of errors, correctly typing out and printing a document) from which a standardised mean difference (*d*) effect size could be computed (e.g. *t* or *F* statistics). Studies were excluded where ceiling effects were noted for performance variates (e.g. Reznich, 1996); where studies which did not use direct tests of learning (e.g. Reznich, 1996, and Weaver, 1988, who used computer anxiety measures); or where a close reading of the study method indicated the presence of confounding variables (e.g. Millslagle, 1996) or an operationalisation of the control condition which included minimalist design principles (e.g. Lyn, 1997).

In the present study, *d* was defined as the difference between the means of the integrated and non-integrated conditions divided by the pooled standard deviation, corrected for the slight bias due to small sample sizes (Hedges & Olkin, 1985). Inspection of the selected studies did not suggest that they could be differentiated according to study quality: all studies used random assignment to groups and had carefully designed and measured dependent variables, although some number of studies had small sample sizes (less than 10 per group). Details of the included studies are presented in Table 1.

Table 1
Summary of studies included for meta-analysis

Study	**Standardised Mean Difference (*d*)**	**Experimental Condition**	**Learning domain**	**Performance Variate**	**Type of testing**
Gong & Elkerton (1990)	2.34	Minimal manual	Occupational safety software	Number of errors	One on one testing
Lohmann (1994) Exp.1	2.26	Genetic growing system	Word processing, spreadsheet & database suite	Performance test score	Group testing
Carroll et al. (1987) Exp.1	1.63	Minimal manual	Word processing	Performance test score	One on one testing
Gong (1990)	1.54	Minimal manual	Automotive assembly software	Number of errors	Not stated
Van der Meij & Lazonder (1993)	1.26	Minimal manual	Word processing	Performance test score	One on one testing
Wendel & Frese (1987)	1.14	Minimal manual	Word processing	Free recall of manual commands	One on one testing
Lazonder & van der Meij (1993)	1.01	Minimal manual	Word processing	Performance test score	Group testing
Lohmann (1994) Exp.2	0.95	Genetic growing system	Word processing, spreadsheet & database suite	Performance test score	Group testing
Carroll et al. (1987) Exp.2	0.80	Minimal manual	Word processing	Performance test score	One on one testing
Oatley, Meldrum, & Draper (1990)	0.77	Minimal manual	Word processing	Performance test score	Group testing
Carroll et al. (1985)	0.68	Minimal manual	Word processing	Performance test score	One on one testing
Ramsay & Oatley (1992)	0.64	Minimal manual	E-mail programme	Performance test score	Not stated
Lohmann (1994) Exp.3	0.61	Genetic growing system	Word processing	Performance test score	Group testing

Estimates of mean effects weighted for sample size, and 95% confidence intervals around these estimates for both overall analyses and moderator analyses were derived from random effects tests described in Shaddish and Haddock (1994), using the meta-analysis module in Zumastat (Jaccard, 2004). Tests of homogeneity of between- and within-group effects are given with Q statistics, which are approximately distributed according to the χ^2 distribution with k – 1 degrees of freedom, where k is the number of effects. A significant Q statistic indicates the observed degree of variability across moderator categories (Q_B), or effects within categories (Q_W), is greater than would be expected through sampling error alone.

Results

Using Cohen's (1988) criteria for effect size magnitudes, the weighted mean effect size of the 13 effects was large, d = 1.12 (95% confidence interval 0.83 – 1.41). The homogeneity statistic was not statistically significant, Q_B = 14.56, df = 12, p = 0.266, indicating that the variability in effect sizes was not greater than might be expected by chance.

Follow-Up Meta-Analysis I – Principle 3: Support error recognition and recovery.

Three studies (total *n* = 118) were located which addressed aspects of this principle, comparing a minimal manual condition with a strong emphasis on error recovery with a condition with little or no such emphasis. Details of studies are presented in Table 2. Error recovery instructions are "designed to assist the user in avoiding, recognizing, and recovering from errors" (Gong & Elkerton, 1990; p.102). Lazonder and van der Meij (1994) describe good error information as consisting of a characterization of the system state to detect and identify the error; conceptual information about its likely cause; and action statements for its correction.

Table 2
Summary of studies included for "error recovery" meta-analysis

Study	Standardised Mean Difference (*d*)	Learning domain	Performance Variate
Lazonder & van der Meij (1995)	0.70	Word processing	Error correction task
Lazonder & van der Meij (1994)	0.55	Word processing	Corrective knowledge test
Gong & Elkerton (1990)	0.45	Occupational safety software	Number of errors

Results

The weighted mean effect size of the 3 effects was moderate, d = 0.59 (95% confidence interval 0.22 – 0.96). The homogeneity statistic was not statistically significant, $Q_B = 0.28$, $df = 2$, $p = 0.87$.

Follow-Up Meta-Analysis II - Principle 4: Support reading to do, study and locate.

Three studies (total *n* = 120) were located which addressed aspects of this principle, in particular, the heuristic of "slashing the verbiage". Often, instructional materials contain information that is irrelevant to the learner's current goals. Common sources of such information include system introductions and requirements. By adding to the manual's bulk, these sources of information may reduce trainee motivation to "plough through the verbiage" in search of goal-relevant information. "Minimal" manuals are thus designed to remove redundant or extraneous sources of information wherever possible, generally reducing the length of the manual markedly as a result. Details of studies are presented in Table 3.

Table 3
Summary of studies included for "slash the verbiage" meta-analysis

Study	**Standardised Mean Difference (*d*)**	**Learning domain**	**Performance Variate**
Black, Carroll & McGuigan (1987)	1.69	Word processing	Time to complete test exercise
Gong & Elkerton (1990)	1.26	Occupational safety software	Number of errors
Warner (1988)	0.55	Database use	Performance test score

Results

Using Cohen's (1988) criteria for effect size magnitudes, the weighted mean effect size of the 3 effects was large, d = 0.89 (95% confidence interval 0.36 – 1.42). The homogeneity statistic was not statistically significant, Q_B = 3.84, df = 2, p = 0.15.

Discussion

The results of the primary meta-analysis are strongly supportive of the minimalist approach to instructional design for learning to use ICTs. Across a broad range of instructional domains, adult learners who learned from materials designed according to a minimalist, learner-centred approach (either minimal manuals or genetic growing systems) outperformed those who learned using a traditional system-centred approach (either from conventional manuals, or from an instructor who emphasised drill and practice rather than facilitating student-centred activity). The observed mean effect favouring minimalist conditions, d = 1.12, compares very favourably to several benchmarks in educational research (e.g. Hattie, 1987; Tallmadge, 1977). Tallmadge (1977; p.34), in a review of educational evaluation best practice, noted, "[o]ne widely applied rule is that the effect must equal or exceed some proportion of a standard deviation - usually one-third, but at times as small as one-fourth - to be considered educationally significant". The average effect found in the primary meta-analysis, and the lower bound of its confidence interval, clearly exceeds this benchmark.

Follow-up meta-analysis of tests of the minimalist principle "supporting error recovery" also found a moderate to strong average effect across available studies (d = 0.59), supporting previous claims for the educational significance of this design principle. More recent research has replicated and extended these effects in a variety of educational settings. Recent work on error recovery (e.g. Gully, Payne, Koles, & Whiteman, 2002; Heimbeck, Frese, Sonnentag, & Keith, 2003) has replicated previous minimal manual-based findings, while extending this work to investigate various aptitude-treatment interactions, including ability, "Big 5" personality characteristics, and goal orientation.

Likewise, the follow-up meta-analysis of the principle of "slashing the verbiage" in self-instructional manuals found a large average effect (d = 0.89). This result is in accord with a large body of experimental educational research which has demonstrated the negative effects of redundant information on learning (e.g. Cerpa, Chandler, & Sweller, 1996; Chandler & Sweller, 1996; Mayer, Bove, Bryman, Mars,

& Tapangco, 1996; Reder & Anderson, 1980, 1983; Sweller & Chandler, 1994; Ward & Sweller, 1990). Instructional design theories drawing on theories of human cognitive architecture, such as Sweller's Cognitive Load Theory (e.g. Sweller, 2003) and Mayer's Cognitive Theory of Multimedia Learning (e.g. Mayer, 2001), argue that redundant information is a source of extraneous cognitive load, which reduces the resources available in working memory for learning. The size of this average effect (d = 0.89) compared with that for the primary meta-analysis (d = 1.12) suggests that the reduction of redundancy might be the key driver of learning gains following minimalist redesigns. Further research using factorial experimental designs, allowing the simultaneous testing of the above principles and their interactions, would be necessary to test this speculation.

While the above results are broadly supportive of the minimalist approach to instructional design, it is vital to recognise the considerable effort that should go into such redesigns. Minimalist researchers (e.g. Carroll et al., 1987-1988; Carroll, 1998; Gong, 1990; Ramsay & Oatley, 1992) have emphasised that minimalist learning materials should be developed through an iterative process, including usability testing at each stage with actual end-users. This approach helps to ensure a more learner-centred approach, as designers' theories of the task domain and appropriate instantiation of minimalist design principles and heuristics are explicitly and repeatedly tested. Gong and Elkerton's (1990) very large effect (d = 2.34) favouring the minimal manual is likewise attributable to the effort put into designing the manual according to a GOMS-based task analysis (Card, Moran, & Newell, 1983) of the instructional domain.

Although such efforts are expensive, the return on investment may be considerable. Merritt (1997) has noted the example of the Stuart Title Guarantee Company, who developed a hypertext application using minimalist design principles. Their total development costs, including considerable usability testing, were $500,000. Subsequently, a client who stated they "had been considering his needs" ordered between 40 and 50 copies per month, resulting in a return on investment in only five months, and in the first year 5000 units were sold for a profit of $19,000,000.

Historically, the poor quality of much ICT documentation has often placed a considerable burden on learners, who have struggled with verbose, incomprehensible, system-focused jargon that fails to support solving real problems. The present study indicates minimalist design of documentation leads to substantial benefits for learners.

Authors' note

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