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Effects of VDT and paper presentation on consumption and production of information: Psychological and physiological factors

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Abstract

Two experiments were performed to investigate the influence of VDT (video display terminals) and paper presentation of text on consumption of information (Study 1) measured in the form of convergent production and production of information (Study 2) measured in form of divergent production. The READ test of reading comprehension was used as the convergent task whereas the "Headlines" test was used as the divergent task. Several other factors pertaining to performance were also studied including the PANAS test of positive and negative affect, the STH test of stress, tiredness and hunger, the TRI (Technology Readiness Inventory) and the SE test of stress and energy.

The results show that performance in the VDT presentation condition where inferior to that of the Paper presentation condition for both consumption and production of information. Concomitantly, participants in the VDT presentation condition of the consumption of information study reported higher levels of experienced stress and tiredness whereas the participants in the VDT presentation condition of production of information study reported only slightly higher levels of stress.

Although the results are discussed in both physiological and psychological terms arguments are made that the incremental effects of VDT text presentation stem mainly from dual-task effects of fulfilling the assignment and working with the computer resulting in a higher cognitive workload.

Keywords: Convergent; Divergent; Mental workload; VDT; Stress; Tiredness

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1. Introduction

The current influx of computers in human behavior can be found in all aspects of society. Using Sweden, with one of the worlds highest levels if ICT (Information and Communication Technology) proliferation as an example, one can see that ICT is applied with increasingly greater leaps (Observatoriet för IT, 2001) and integrated into individuals' daily agenda, at home (Bergström & Wadbring, 1999), in school (Wästlund, Norlander, & Archer, 2001) and at work (Arbetarskyddsstyrelsen, 1999; Hintze, 2002; Kopf, 2002).

Although computers can be used for a variety of activities, the types of work performed with computer assistance can, to a large extent, be divided into two categories: Consumption of information and Production of information. Both types of work are based upon cognition, briefly described as the process through which information is encoded, organized, stored, remembered and applied (Martinsen & Kaufmann, 1999). Both consumption and production of information entail the formation of new cognitive structures and novel combinations of ideas or thoughts. Ghiselin (1963) identifies these consequences of cognitive processes as psychological aspects of creativity. The concept of creativity is complex and multifaceted but a fundamental distinction has been made between input-creativity, the ability or process of interpreting information and forming abstract connections between concepts, and output-creativity, the ability or process of generating new or cultivated material (Partridge & Rowe, 1994).

The input- versus output-creativity distinction may be traced to Guilford (1967) who separates two forms of creative production based on the possible variations in the number of correct solutions. Divergent production implies the presentation of a large number of solutions or attempts at explanation. This effect arises when, as consequence of the subject's construction and evaluation of his/her own results, the possibilities are limitless. The absence of restrictions leads to difficulties in the qualitative evaluation of divergent production. Amabile (1996) states that a product is creative to the extent that suitable observers, independent of each other, judge the product as creative. Suitable observers must possess a competence within the enterprise that the product is aimed at. Thus, creativity may be seen as the quality of a product judged creative by competent judges.

Convergent production results in the synthesis of a correct solution to a problem, the right and unique answer (Guilford, 1967). Convergent production builds upon logic and deduction. Although searching within divergent problem-solving is much broader than for convergent, the latter offers clearer criteria to achieve the goal (Guilford, 1967).

Consequently, consumption and production of information may be described and measured in terms of convergent and divergent production. Consumption of information presumes that individuals draw a specific conclusion about the material at hand whereas production of information provides scope for many solutions. It should be borne in mind that work in a computerized environment consists of combinations of both types of creative production. Consumption of information in a computerized environment consists fundamentally of reading, text perception, which

can be described as a reception of text through vision as well as an exploitation of the text content in different applications (Edfeldt, 1982).

Perception refers to the information content of the visual impression, resulting from the coordination of the eyes and the external information (Arai, 1999). Rather than being a one-way process, perception may be regarded as a cycle of information refinement (Neisser, 1976). The cycle consists of selection and analysis of information from the surroundings; selection is determined by internal expectations which in turn are regulated by the cognitive set-up, the mental structures, that an individual possesses (Neisser, 1976). Attitudes, too, form part of the cognitive set-up (Hogg & Vaughan, 1998). The combination of set-up and attitude exert a meaningful role upon both perception of and understanding of the surroundings underlying the experience and evaluation of stimuli (Ajzen, 2001).

In view of the occupational status of computers, positive attitudes to computers are important (Jones, 1994), as these lead to lower levels of computer-anxiety, user-comfortability and in general a liking for computers according to (Parish & Necessary, 1996). Much research describes the relationship of attitudes to and subsequent usage of computers (e.g. Smith, Caputi, & Rawstorne, 2000). Although this relationship does not address the question of attitudes and performance in computer-served environments directly, one may assume that a positive connection facilitates the regular usage necessary for skill development and subsequent improvement.

As early as 1985, Belmore warned that text presentation on video display terminals (VDTs) was of less quality than text presentation on paper and leading to a poorer understanding of the material (Belmore, 1985). Furthermore in a comparison between information searches on either paper or VDT, the later was showed to lead to a slower reading speed (Gray, 1991). Nine years after Belmores' study, Rice (1994) found no difference between VDT reading and paper reading for text remembrance, implying that mode of text presentation was not critical. Further, he found no difference between paper and VDT presented text for understanding. Nevertheless, reviews concerned with comparisons of VDT versus paper text reading holds that paper text is superior (e.g. Ziefle, 1998). The reviewed studies have focussed upon various technical aspects of VDT text presentation with the general conclusion the performance impairment is due to poor VDT quality, whereby eye-muscles modulating vision tire more quickly with text of inferior quality leading to worsened perception.

Mayes, Sims, and Koonce (2001) suggest that the performance detriment is not just a result of higher visual burdening but also of an increased burdening of the cognitive component of perception. Thus, the reallocation of resources from perception to cognition offers a complementary explanation for increased 'tired-eyes' during VDT reading (Mayes et al., 2001). Additionally, consumption and production of information in a computer aided environment results in a dual-task situation consisting of both the completion of the assignment at hand and of handling the computer (Proctor & Van Zandt, 1994). Simultaneous treatment of dual tasks induce a conflict situation that eventually leads to delay in information analysis, even long after the perception instance (Jolicoeur & Dell, 1999; Koch & Prinz, 2002). This

delay resulting in an increased workload may lead to performance deterioration, most marked under conditions of stress induced by time pressures (Waern, 1990). Further the increased workload, itself, may induce elevations in stress levels through users experience of unfulfilled assignment completion (e.g. Kahneman, 1973). The inverted-U function "Yerkes-Dodson law" (Yerkes & Dodson, 1908) implicating detrimental effects of high levels of arousal for information processing was established almost a century ago, but stress experiences with low levels of arousal can also result in performance detriment as the stressor, itself, acquires distracting properties (APA, 1994).

Based on the increase in computer proliferation and the conflicting results in studies regarding VDT and paper presented text the aim of this paper is to examine the effects of VDT and paper presentation on Consumption of information (Study 1) in form of convergent production and Production of information (Study 2) in form of divergent production with consideration of workload and stress.

2. Study 1

2.1. Methods and materials

2.1.1. Selection and participants

The sample consisted of students at the University of Karlstad, Sweden, who were offered the opportunity of participating and chose to do so. The in total 72 participants where divided into two groups (18 males and 18 females in each) which according to two-way ANOVAs with group and gender as independent variables, showed no significant differences (p's > 0.05) in regards to either age ($M = 24.93$, $SD = 4.77$) nor number of College grades ($M = 2.03$, $SD = 1.07$). Participants began using IT around 1996 ($SD = 1.88$, *Range* = 1990–1999) and for a mean of 5.51 h ($SD = 5.44$, *Range* = 0–30) per week. Participants pursued a variety of computer uses over 8.71 h, on average, ($SD = 7.27$, *Range* = 0–40) per week, and sent out a mean of 5.49 emails ($SD = 5.57$) per week. Two-way ANOVA with Type of Presentation (see Section 2.2) and gender as independent variables and with the above background factors as dependent variables did not indicate any significant group differences pertaining to Gender with regard to the year IT was first used, number of IT hours per week and other computer uses per week (p's > 0.05). There was, however, a significant difference pertaining to the number of emails sent per week ($p < 0.01$), whereby the Paper-presentation ($M = 7.83$, $SD = 6.79$) group sent more emails compared with the VDT-presentation group ($M = 3.33$, $SD = 1.88$). Furthermore, three personality tests were presented to obtain more data on background factors. There were no significant differences with regard to TRI ($M = 2.21$, $SD = 0.33$) or for the stress section of SE ($M = 2.60$, $SD = 0.98$) but there was an effect of Gender upon the energy section of SE whereby female participants ($M = 3.23$, $SD = 0.79$) displayed higher values than male participants ($M = 2.80$, $SD = 0.92$). There was no significant difference (p's > 0.05) with regard to Positive affect ($M = 3.16$, $SD = 0.61$) or Negative affect ($M = 2.02$, $SD = 0.58$). Last of all a

two-way MANOVA with Type of Presentation and gender as independent variables and the Pre-STH (see Section 2.2.1) test containing measurements of stress ($M = 55.21$, $SD = 18.64$), tiredness ($M = 54.56$, $SD = 17.94$) and hunger ($M = 43.40$, $SD = 26.45$ showed no significant differences (p's > 0.05).

2.2. Design

Consumption of information was measured in form of convergent production by application of a reading-comprehension test, derived by the Board of Higher Education. Depending on the Type of Presentation (VDT or Paper) the participants belonged to the test was either presented on a VDT by means of a pdf file viewed in Acrobat reader, with all functions enabled, or on paper where the contents of the pdf file had been printed. Group allocation was arranged as follows: each participant himself/herself chose at which time he/she would like to participate in the study. In doing this, they also chose what type of presentation they would be subjected to as the various occasions only contained one condition. The independent variables of the study were Type of presentation (VDT, Paper) and Gender (male, female). The dependent variables of the study were: number of correct answers on the READ test as well as Post-STH (see Section 2.2.1).

2.2.1. Instruments

TRI – Technology Readiness Index. The TRI test (Parasuraman, 2000) is a multiple item scale design used to measure individuals' approach in coming to terms with technology and their willingness to tackle new technologies. The test consists of 36 statements and the subject's task is to respond whether or not he/she agrees with or does not agree the statement on a 5-point scale, from 0, ''absolutely do not agree'', to 4, ''agree completely''. The statements may either be divided up into four subscales that measure Optimism regarding technology (OPT), Innovation (INN), Distress/Disability (DIS) and Insecurity (INS), or a summation each subject's total score may be derived. This total score was applied also in the present instance. Parasuraman (2000) reports that the internal concordance between the four scales varies between 0.74 and 0.81 (Chronbach's α). The test has been translated to the Swedish language through the application of the ''translation–back translation'' technique recommended, for example, by Triandis (1994). The translation was carried out by linguists from the Department of English Language, University of Karlstad. A brief description of different components of the test follows:

- Optimism (OPT) – associated with a positive view of technology and a belief that offers individuals increased control, flexibility and effectiveness in their lives.
- Innovation (INN) – associated with the tendency to be a pioneer technologically and leading figure in ''brainstorming''.
- Distress/Disability (DIS) – associated with the experience of 'loss of control' and a feeling of being overwhelmed.
- Insecurity (INS) – associated with a suspicion of technology and a scepticism the possible that technical matter may work correctly.

- TRI Total score (TRI) – This is derived by summating the mean number of points of the four components (OPT, INN, DIS, INS), after a reciprocal transformation of the points for DIS and INS has been performed. This measure refers to an individuals' propensity to adapt and acquire new technical abilities.

SE – stress and energy. The SE instrument is a self-estimation instrument that measures individuals' energy and experience of stress (Kjellberg & Iwanowski, 1989). SE makes evaluations in two subscales that clarify the affective level of individuals in regards to experienced stress and experienced energy. The SE test consists of 12 adjectives that describe commonly occurring affective states. The response alternatives are presented on 6-point scales that vary between 0, "not at all", and 5, "very much". The SE test has been applied to a wide range of studies within work and occupation research (Iwanowski, 1989; Kjellberg & Iwanowski, 1989; Razmjou, 1989) and has through these applications become standardized with a high level of validity. The test was derived originally from a early, well-used checklist "'Mood Adjective Check-List", constructed by Nowlis and Green (Nowlis, 1965). The present SE version was most lately modified by Kjellberg & Iwanowski (1989).

PANAS – positive affect and negative affect scales. The PANAS instrument (Varg, 1997; Watson, Clark, & Tellegen, 1988) estimates the degree of affectivity, both positive and negative, in subjects. PANAS consists of 20 adjectives, 10 pertaining to positive affect and 10 to negative affect. The subjects' task is to estimate how they have felt lately (Watson et al., 1988), in the present study during the last five working days. Estimations are made on a 5-degree scale ranging from 1, "not at all" to 5, "very much". The 10 positive adjectives are summated to an estimation of positive affect, PA, and likewise the 10 negative adjectives are summated to an estimation of negative affect, NA.

Higher Education Entrance Examination – READ test. The READ test is designed to measure Swedish language reading comprehension. The test consists of 10 pages containing five different texts, averaging 1000 words, which are followed by four multiple-choice questions each. As the scoring is a simple summation of correct answers, the respondents can receive up to 20 points. The questions are constructed to be as varied as possible and are distributed in such a way that the whole text is made use of. Each time a new READ test is developed there is no predetermined model designed to cover the different cognitive levels. The text, itself, and its characteristics determine how the task is constructed to deal with cognition. The essential point is that the texts represent that type of text material that students are expected to tackle in the course of their studies, i.e. the text must possess an "ecological validity". It is also important that the assignments in the texts focus upon realistic and interesting aspects in the text, artificial and superficial aspects are avoided. The test's assignments are thought in general to cover three cognitive levels, remembering, understanding and deduction, of which understanding and deduction dominate. The test is thereby a convergent problem-solving test (Guilford, 1967). All information concerning the READ test was obtained from a work material from the unit for pedagogical measurements that constructs and develops the test. Since the Higher Education Entrance Examination is continually renewed there does not exist any published material.

STH – stress–tiredness–hunger. The object of this test is to assess the participant's current state of experienced stress, tiredness and hunger. The scale consists of a 100-mm long line with two extremities and a mid point. Subjects were required to mark, with a cross, a point on the scale were he/she considered it most appropriate. This type of scaling method presenting a 100-mm long line, the VAS (Visual Analogue Scale), is well established through a variety of studies requiring psychological testing. The test was presented twice during the course of the study: prior to the READ test (Pre-STH), in order to ensure that the groups where not biased, and after the test (Post-STH), in order to examine the possible effects of the different assignments. The Pre- and Post-STH tests differ in that the Pre test asks the participant to compare his/her currant state with his/her usual state whereas the Post-STH asks the participant to make a comparison with the Pre-STH test. The Post-STH test was followed by an evaluation of type of presentation where subjects were required to write down whether or not they experienced any problem with the mode of presentation (VDT or Paper) and, if so, what type of problem.

2.2.2. Computer information

The computers used in the investigation were manufactured by DELL, "OptiPlex GX110" 633 MHz with a 17-in. TCO 99 VDT. Screen display resolution was 800×600 and 16 bits graphic colour resolution. The update frequency on the display unit was 60 Hz. The program used for the READ test was "'Adobe acrobate reader 3.01" and the format of the test was pdf. The mouse used during the test was a Microsoft standard mouse PS/2, with rubber ball.

2.2.3. Procedure

The participants were recruited at the University of Karlstad, Sweden, from various localities and after a brief information, recounting that this was a data collection study within psychology, were each allowed to decide whether or not they wanted to take part. Each student was allowed to choose on which of the six occasions he/she would do so. After the participant had chosen the time-point, he/she registered name and telephone number making a more or less formal obligation.

The first day of the study concerned consumption of information through VDT. Computers and experimental room were prepared before bringing participants in. The preparations included: the document that was to be read by all was opened on all the computers and only the VDT was closed, in order to reduce the time required for opening the test as well as any eventual problems that may occur during computer start-up and opening the document.

When each participant had sat down by a computer. He/she then received further instructions including switching off cellphones, reading all the questionnaires carefully so that he/she did not miss anything and to avoid guessing on the READ test but rather to only answer those questions that he/she had managed to read. The latter in order to provide a clearer indication of how far the participant had managed to advance in the time allocated.

Following these relatively short instructions, each participant was allowed to complete the demographic and the Pre-STH questions (see Section 2.2.1). This was

followed by the TRI questionnaire, which in turn was followed by the SE questionnaire. The final questionnaire that the participant completed before the READ test was PANAS (Section 2.2.1).

After all the participants had complete these questions they were instructed to place them beside the computer and the READ test was initiated through the distribution of an answer-pad to the READ test, wherein the instructions to the READ test were presented. After 30 min had elapsed, all the participants were instructed to lay aside their answer-pads in the same place that the earlier completed questionnaires had been placed. A final questionnaire was distributed wherein the Post-STH was completed, but this time in relation to how the participants felt compared with before they performed the READ test. In addition to the three Post-STH questions, the final questionnaire contained an additional two questions concerning whether or not the participant had experienced any problem during the course of the test and whether or not he/she had seen the test before.

During the second day, consumption of information was tested on "ordinary paper". The participants were treated in an identical fashion to the day before when the test was presented over VDT. The only aspect that differed between the groups was that each participant received an envelope containing the READ test that he/she opened instead of turning on the VDT.

2.3. Results

With Type of presentation and Gender as independent variables for all the dependent variables measured, the following effects were obtained.

Two-way ANOVA with Type of presentation and Gender as independent variables and Read as dependent variable indicated a significant effect ($p < 0.02$, $power = 0.67$) with regard to number of correct answers [$F(1, 68) = 5.95$, $p = 0.017$], whereby the Paper-presentation group produced more correct responses ($M = 7.97$, $SD = 2.99$) than the VDT-presentation group ($M = 6.23$, $SD = 3.16$). Table 1 presents the mean (and *SD*) as well as total number of correct readings for male and female participants. There were no significant differences with regard to Gender ($p > 0.05$, $power = 0.23$) nor any interaction effects.

A Pillais MANOVA (2×2 factorial design) with Type of presentation (VDT–Paper) and Gender as independent variables and with Post-STH test as dependent variable indicated a significant effect of condition ($p < 0.01$, $power = 0.98$) but not Gender ($p > 0.05$, $power = 0.61$), nor were there any significant interaction effects ($p > 0.05$, $power = 0.61$). The results of the univariate F tests for each question are described below:

Stress. There was a significant effect of condition [$F(1, 68) = 6.37$, $p = 0.014$], whereby subjects in the VDT condition reported higher levels of stress ($M = 66.37$, $SD = 21.53$) than subjects in the Paper condition ($M = 54.78$, $SD = 20.66$).

Tiredness. There was a significant effect of condition [$F(1, 68) = 8.61$, $p = 0.005$], whereby subjects in the VDT condition became more tired ($M = 72.00$, $SD = 13.21$) than subjects in the Paper condition ($M = 60.19$, $SD = 20.30$).

Table 1
Means (*M*) and standard deviations (*SD*) of number of READ correct responses for male and female participants of the VDT and Paper presentation conditions for the convergent problem-solving assignment

Condition	Male		Female		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*
VDT	6.44	3.03	6.00	3.37	6.23	3.16
Paper	8.67	3.43	7.32	2.40	7.97	2.99

Hunger. There was a significant effect of condition [$\underline{F}(1, 68) = 6.41$, $\underline{p} = 0.014$], whereby subjects in the VDT condition became less hungry ($\underline{M} = 56.89$, $\underline{SD} = 17.69$) than subjects in the Paper condition ($\underline{M} = 67.22$, $\underline{SD} = 16.49$). Table 2 presents the means ($\underline{SD}$'s) for male and female participants, as well as total, for Post-STH responses in the VDT and Paper presentation conditions.

Presented below is a compilation of the various answers to the question concerning the experience of problems during testing. It was found that problems were no due to the READ test, itself, or its construction, but rather the condition and experience. In total, 29 participants (40%) experienced problems during testing, 36% of the participants with VDT and 44% of the participants with the Paper presentation. The different problems have been arranged into the following categories: problems with reading text, difficulties in following the text, pressure of time, difficulties in concentration and 'others' (for percentage incidence of each of the four categories for the VDT and Paper conditions is presented see Table 3).

Examples of problems described by participants are as follows:

Problems with reading text.

VDT: "It's difficult to read text on VDT, bad for the eyes"

Paper: "Difficult text to read, easy to lose the thread"

Difficulties in following the text.

VDT: "Hard work following the text, easier with paper instead"

Table 2
Means (*M*) and standard deviations (*SD*) scores for Post-STH (stress, tiredness and hunger) by male and female participants of the VDT and Paper presentation conditions for the convergent problem-solving assignment

Condition	Post-STH	Male		Female		Total	
		M	*SD*	*M*	*SD*	*M*	*SD*
VDT	Stress	64.78	20.83	68.06	22.75	66.37	21.53
	Tiredness	69.33	13.12	74.82	13.09	72.00	13.21
	Hunger	56.44	22.01	57.35	12.17	56.89	17.67
Paper	Stress	44.33	19.06	64.68	17.26	54.78	20.66
	Tiredness	57.67	20.40	62.58	20.46	60.19	20.30
	Hunger	68.06	14.36	66.42	18.64	67.22	16.49

Table 3
Percentage of problems reported by participants of the VDT and Paper presentation conditions in response to the question concerning experience of problems during the test

Type of problem	VDT (%)	Paper (%)
Problems reading text	14	6
Difficulties following the text	14	–
Pressure of time	–	16
Difficulties with concentration	–	11
Others	8	11
Problems in total	36	44

Pressure of time.
Paper: "Felt the pressure of time over me throughout"

Difficulties in concentration.
Paper: "Concentration and reading technique"

Others.
VDT: "Would have liked to underline"
Paper: "Put everything together"

3. Study 2

3.1. Methods and materials

3.1.1. Selection and participants

The sample, which was obtained in the same manner as for Study 1 consisted of 72 participants which where divided into two groups (18 males and 18 females in each) that according to an ANOVA with group and gender as independent variables, showed no significant differences (p's > 0.05) in regard to Age ($M = 24.07$, $SD = 2.91$) or number of College grades ($M = 2.13$, $SD = 0.91$). Participants began using IT around 1995 ($SD = 3.60$, *Range* = 1990–1999) and for a mean of 8.89 h ($SD = 7.13$, *Range* = 1–35) per week. Participants pursued a variety of computer uses over, on average, 15.47 h, ($SD = 15.46$, *Range* = 0–50) per week, and sent out a mean of 9.54 emails ($SD = 12.98$) per week. Two-way ANOVA with Type of Presentation (see Section 3.2) and Gender as independent variables and with the above-described background factors as dependent variables indicated no significant Group differences with regard to condition, VDT/Paper (p's > 0.05), with regard to first year of IT use, other computer hours per week and number of emails sent per week. However, there was a significant Gender effect upon number of hours per week spent on IT ($p < 0.01$), whereby female participants spent fewer hours ($M = 5.61$, $SD = 4.72$) than male participants ($M = 12.27$, $SD = 7.66$). Three personality tests were presented to obtain more data on background factors. There was a Gender effect upon TRI ($p < 0.05$), whereby the female participants presented lower values ($M = 2.22$, $SD = 0.35$) than male participants ($M = 2.40$, $SD = 0.28$). There were no significant

effects ($p > 0.05$) pertaining to the Stress section of SE ($M = 2.30$, $SD = 1.05$) or for the Energy section of SE ($M = 3.12$, $SD = 1.13$), nor were there any differences with regard to Positive affect ($M = 3.25$, $SD = 0.62$) or Negative affect ($M = 1.95$, $SD = 0.66$). Last of all a two way MANOVA with Type of Presentation and gender as independent variables and the Pre-STH (see Section 3.2.1) test containing measurements of stress ($M = 49.06$, $SD = 19.83$), tiredness ($M = 52.11$, $SD = 19.88$) and hunger ($M = 43.61$, $SD = 25.42$) showed no significant differences (p's > 0.05).

3.2. Design

Consumption of information was measured in form of divergent production by application of the "Headlines" test. Depending on the Type of Presentation (VDT or Paper) the participants belonged to the test was either presented on a VDT by means of a pdf file viewed in Acrobat reader, with all functions enabled, or on paper where the contents of the pdf file had been printed. Group allocation was arranged as follows: each participant himself/herself chose at which time he/she would like to participate in the study. In doing this, they also chose what type of presentation they would be subjected to as the various occasions only contained one condition. The independent variables of the study were Type of presentation (VDT, Paper) and Gender (male, female). The dependent variables of the study were fluency and quality of the answers as well as Post-STH (see Section 3.2.1).

3.2.1. Instrument

- TRI – Technology Readiness Index, see Study 1.
- SE – stress and energy, see Study 1.
- PANAS – positive affect and negative affect scales, see Study 1.
- STH – stress–tiredness–hungry, see Study 1.

Headlines. The verbal creativity test "Headlines" measures divergent production (Ekvall, 1969), and test may be used to predict creative behaviour. The tests assesses ability to transform one unit of information to another, e.g. to derive from a complete newspaper article the essential text that may provide a headline. According to Ekvall (1969), the test is equivalent to the North American "plot titles" (Guilford, 1967). Ekvall (1969) considers that the test is applicable mainly in groups with a high level of verbal potential since it places a demand upon rapid acquisition and understanding of speech material. This implies that the test is relatively limited to groups with higher levels of formal education. There are no noticeable gender differences for higher education. According to previous investigations (Ekvall, 1969), "Headlines" covaries strongly with "bricks" which is also a test for divergent production. "Headlines" correlates also with two other verbal tests: "W1" and "Double meaning". The test requires that one write down as many headlines as possible to short newspaper articles; in the test's original construction this involved four newspaper articles wherein time allocated to each article was 3 min. In the present study, this was modified to encompass 10 articles, with a mean length of 70 words, with a total time limitation of 30 min. In addition to the quantitative judgements, number of headlines, the test included a qualitative assessment, carried out by two journalists who subjectively

judged every headline on a scale of 1–5. Interjudge reliability was 0.531. Ekvall (1969) considers that there are different variants in judgements to choose between. One may take into consideration all of the subject's headlines or just the two or three best headlines to each articles may be taken. In the present study, the 20 best headlines for each subject were summated to a mean value. The decision to take the 20 best headlines from the whole test instead of the two best from each article was due to the fact that all the subjects did not write headlines to every article.

3.2.2. Computer information

See Study 1.

3.2.3. Procedure

With the exception of the exclusion of the READ test and the inclusion of the Headlines test, the procedure was in all respects a replication of the procedure followed in Study 1.

3.3. Results

With Type of presentation and Gender as independent variables for all the dependent variables measured the following effects were obtained:

Two-way ANOVA with Type of presentation and Gender as independent variables and Headlines as dependent variable indicated a significant effect ($\underline{p} < 0.05$, $\underline{power} = 0.57$) with regard to the number of headlines [$\underline{F}(1, 68) = 4.74$, $\underline{p} = 0.033$], whereby participants in the Paper presentation condition produced a greater number of headlines ($\underline{M} = 39.50$, $\underline{SD} = 12.67$) than those in the VDT presentation condition ($\underline{M} = 33.42$, $\underline{SD} = 10.98$). There were no significant differences with regard to Gender ($\underline{p} > 0.05$, $\underline{power} = 0.24$), nor any interaction effect ($\underline{p} > 0.05$, $\underline{power} = 0.09$). Table 1 presents the means (and $\underline{SD}$) as well as total number of headlines for male and female participants Table 4.

Two-way ANOVA with Type of presentation and Gender as independent variables and Quality as dependent variable indicated no significant differences ($p > 0.05$, $power = 0.09$) between the two types of presentation, VDT and Paper, nor any significant effect of Gender ($p > 0.05$, $power = 0.23$), nor was there any significant interaction effect ($p > 0.05$, $power = 0.25$). Table 5 presents the means (and SD) as well as total number of adjudged quality of headlines for male and female participants.

A Pillais MANOVA (2×2 factorial design) Type of presentation (VDT–Paper) and Gender as independent variables and with Post-STH as dependent variable did not indicate any significant effects with regard to condition ($p > 0.05$, $power = 0.40$) and with regard to Gender ($p > 0.05$, $power = 0.24$), and there was no significant interaction effect either ($p > 0.05$, $power = 0.61$). Nevertheless, it may be worthwhile to note that with regard to stress there was a weak trend, $p = 0.076$, whereby subjects in the VDT condition reported more stress after testing ($M = 54.00$, $SD = 20.53$) than subjects in the Paper condition ($M = 45.50$, $SD = 19.74$). Table 6 presents the means (SDs) for male and female participants, as well as total, for Post-STH responses in the VDT and Paper presentation conditions.

Table 4
Means (*M*) and standard deviations (*SD*) for number of Headlines derived by male and female participants of the VDT and Paper presentation conditions for the divergent problem-solving assignment

Condition	Male		Female		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*
VDT	30.83	10.93	36.00	10.70	33.42	10.98
Papper	38.50	10.90	40.50	14.47	39.50	12.67

Table 5
Means (*M*) and standard deviations (*SD*) of scores for adjudged quality as performed by male and female participants of the VDT and Paper presentation conditions for the divergent problem-solving assignment

Condition	Male		Female		Total	
	M	*SD*	*M*	*SD*	*M*	*SD*
VDT	2.24	0.36	2.43	0.26	2.34	0.32
Paper	2.30	0.24	2.29	0.40	2.29	0.32

Table 6
Means (*M*) and standard deviations (*SD*) of scores for Post-STH (stress, tiredness and hunger) by male and female participants of the VDT and Paper presentation conditions for the divergent problem-solving assignment

Condition	Post-STH	Male		Female		Total	
		M	*SD*	*M*	*SD*	*M*	*SD*
VDT	Stress	53.33	20.65	54.67	20.98	54.00	20.53
	Tiredness	59.56	15.71	51.22	23.98	55.39	20.42
	Hunger	59.56	13.98	63.33	13.17	61.44	13.52
Paper	Stress	39.94	20.62	51.06	17.67	45.50	19.74
	Tiredness	56.50	23.25	53.67	22.92	55.08	22.80
	Hunger	69.83	18.10	64.27	22.43	67.06	20.28

4. Discussion

The present study generated two main findings: (1) consumption of information measured in form of convergent production (Study 1) functioned more effectively with text presented upon Paper than upon VDT, and (2) production of information measured in form of divergent production (Study 2) generated a greater number of alternative answers in the condition where the assignment was presented upon Paper than upon VDT.

The first main finding showed that consumption of information, measured by a test of reading comprehension, is more difficult when the assignment is presented upon a VDT than upon paper. VDT presentation led to fewer correct responses, to a greater level of experienced tiredness and an increased feeling of stress.

The paper presentations superiority in generating more responses that are correct may involve both physiological and psychological explanations. The former refers to

the quality of the text configuration, due to which the acquisition of information proceeds more slowly as the consequence of the inferiority VDT text configuration compared to ordinary paper (e.g. Belmore, 1985; Gray, 1991). Under circumstances of a strictly limited schedule for the assignment, it is not surprising that conditions leading to greater time consumption in task completion will induce performance deterioration.

Nevertheless, the degree of consensus regarding a requirement of longer reading time for VDT, as opposed to paper, presented material is not quite convincing (e.g. Rice, 1994) which necessitates a consideration of possible psychological mechanisms. Work in a computer-aided environment entails that in addition to the task requirements of the assignment one must also handle the computer equipment. The original or basic assignment of Consumption of information is thus combined with the task of coping with computer operative requirements (Waern, 1990) resulting in a dual-task situation that may explain the observed performance deterioration (Jolicoeur & Dell, 1999; Koch & Prinz, 2002).

The observed increased tiredness may also be due to either physiological or psychological factors. In the former case, assuming an inferior quality of the VDT text configuration, a greater mobilization of both perceptual and executive cognitive resources is invested in order to compensate for the deficiency of the information presentation. In the latter case, assuming the combination of problem-solving assignment with operative coping resulting in a dual-task assignment necessitates a greater mobilisation of cognitive resources to compensate for the added workload.

Irrespective of model of explanation the heart of the matter is an increase in cognitive demands; either as a result of reallocation of resources from cognition to perception or as a result of another task being added to the original assignment. Increased cognitive demands not only influence tiredness but also the appraisals of the task-situation coping resources (Taylor, Kemeny, Reed, Bower, & Gruenwald, 2000). From a psychophysiological perspective the question is purely academic. Increased cognitive demands combined with an increased burden of work presents a formula for inevitable psychophysiological reactions as expressed by elevated stress levels (Lovallo, 1997). Stress, in itself, may cause both performance deterioration and improvement but stress caused by task-unrelated responses leads to performance deterioration (Amabile, 1996). This might explain the fewer correct responses and the higher levels of experienced stress reported by participants in the VDT group of Study 1.

The second main finding showed that production of information, as assessed by the "Headlines" test, resulted in a higher level of fluency in the Paper condition than the VDT condition, without affecting the extent of the quality of headlines. Participants in the VDT condition report a higher, albeit not significantly so, level of stress.

Essentially, these findings confirm those of the first study and, may be explained in the same manner. However, several methodological discrepancies between the two studies require consideration. In addition to the different forms of the assignments, i.e. consumption versus production of information, there was a discrepancy too in the time dimension. The consumption of information assignment was arranged so that participants had 30 min in which to complete the assignment whereas the

production of information assignment was arranged so that participants were required to spend 30 min upon the task, the former necessitating completion with the latter requiring only compliance.

In addition, under the different conditions of assessing one's own performance it is possible that the Consumption of information assignment motivated participants to greater efforts, which may explain the higher stress level and increased tiredness, compared to the levels, reported in the Production of information assignment.

Further, the length of the respective texts is another important methodological discrepancy. The convergent assignment text consisted of five stories each of 1000 words, whereas the text of the divergent assignment consisted of 10 articles, each a mean of 70 words, the latter therefore requiring a markedly less amount of time to both read the text and cope with computer operatively. Finally, there was discrepancy in the extent of IT and computing experience between the participants of Study 1 and those of Study 2: the former starting in 1996, compared to 1995 in the latter, had accrued only 61.9% of the hours of IT per week, 56.2% of the hours of computing and sent out only 57.5% of the number of emails, of the latter Study 1 participants. Nevertheless, despite all these discrepancies both studies demonstrated inferior assignment performance in the VDT condition, implying plausible stability in the main findings of both studies.

It is important to bear in mind that the performance deterioration of divergent problem solving in the VDT condition afflicted fluency and not quality. The lack of any difference between the VDT and Paper conditions for judged quality may be an effect of the assignment configuration with regard to either the shorted time participants invested upon the computers and text or to the assignments divergent nature. Divergent production demands a flexibility of thought processes (Lubart, 2001). It is thus possible that the dual-task nature of the original assignment combined with operative coping in the VDT condition facilitates flexible thinking by ensuring that individuals 'shift gears' between different avenues.

In sum then, despite the methodological discrepancies observed, both experiments showed that the VDT presentation in varied degree impaired performance and increased participants' experience of stress and tiredness. Unfortunately, the methodological discrepancies between the two studies make it difficult to conclude whether the variations in results stem from the different natures of the assignments, i.e. convergent or divergent, or if they are a result of the different amounts of text. Neither is it possible to conclude the cause of the observed effects. However, the fact that the participants in Study 2 (production of information) performed and responded in a similar fashion as the participants in Study 1 (consumption of information) despite the considerably smaller amount of text in the assignment can only be interpreted as an indication that the psychological effects of the dual-task assignment is a central component in the detrimental effects of VDT presented text. This notion corroborates that of Mayes et al. (2001), who showed the cognitive workload plays an important role for performance in computer-aided environments.

Whatever the cause of the observed effects, it is important that future research shed further light upon them. Computers where in the words of Edwards (2001) invented in order to save time and let people engage in more complex questions or

leisure time; not as shown in this study, to impair performance and diminish the experience of work.

To further investigate the causes of the observed effects and determine how to avoid them is therefore necessary, as the objective must be a computer-aided work environment that minimizes the negative effects, facilitates performance and optimizes individual wellbeing.

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