

**Consumption: Multiple Screens and Attention TVX 2014, June 25–27, Newcastle Upon Tyne, UK**

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**Figure 1. Vi**

A ABSTRACT W We introduce a a

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**Attentio**

Daniel Vata fan cel Mare o 720229, Rom u@eed.usv.ro

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**Consumption: Multiple Screens and Attention TVX 2014, June 25–27, Newcastle Upon Tyne, UK**

**112 RELATED WORK**

bottom-up and top-down processing [23]. For example, some The simplest form to emulate a multi-screen environment is

stimuli attract attention because of their stringent nature (e.g., to define individual screens as part of a video projection, with

a quick motion or a telephone ring), which makes our brain all screens controlled by the same computer [25].

process information at a preconscious level. On the other Alternatively, physical screens can be put together to create

hand, top-down processing represents the act of individuals multi-screen environments by using platforms that control

controlling their attention toward achieving a specific goal. the distribution of content. Phone as a Pixel is one such

Finally, attention is known to be overt (i.e., when eye gaze platform that can scale up to hundreds of displays [20].

attends to some region in space) and covert (mental focus can More screens deliver more content and offer more control to viewers. Conversely, they may also have side effects on visual attention and task performance. In this section, we review previous work that showed interest in visual attention in general, but also in conjunction with the TV set.

shift without necessarily moving the eyes) [14]. Overt attention is sequential by using eye saccades (e.g., ballistic movements) and fixations (e.g., the eye gaze stops at some spatio-temporal stable area). In contrast, covert attention can process several stimuli in parallel. Humans are known to be able to simultaneously attend to 7 ± 2 stimuli at once [13]. Multi-screen environments and task performance Multi-screen environments have been investigated in terms of attention demands [16,17] and their effects on task performance [7,22]. For example, Rashid et al. [16] explored the cost of switching attention between the small display of a mobile device and a large screen, and reported decreased user performance because of the adaptation mechanisms that occur when shifting eye gaze between the two screens. Tan and Czerwinski [22] addressed the effect of visual separation between displays and physical discontinuities, such as monitor bezels. They found that discontinuities do not affect users’ performance, but displaying content on screens positioned at different depths has small yet detrimental

Visual attention and TV Researchers have found that individual looks at the TV vary in length and people develop different watching strategies to follow content on TV. For example, people may look at the TV only at the right times, just enough to be aware of what is happening, while being engaged in some other activity. When investigating such phenomena, Geerts et al. [9] found that the genre of TV content correlates with how much people talk during watching TV, and that the plot structure influences talking during social television watching. Such findings reveal the importance of top-down attention during the everyday TV watching experience. effects on task performance. Forlines et al. [7] observed

Surprisingly, most TV looks are very short, e.g., 2 seconds, participants performing worse during a visual search task

and can be described as mere glances [10]. This fact can be when the information was displayed at different rotation

characterized with the “hazard look” function that gives the angles on four vertical screens than when presented on a

probability that looks persisting a given length will terminate single screen. The authors of that study concluded that

in the next half second. Once a look begins, it is likely to scanning of multiple views added to the length of the task,

terminate in the first second, with a hazard peak at 1−1.5 but not to its accuracy.

seconds. Hawkins et al. [10] investigated this phenomenon

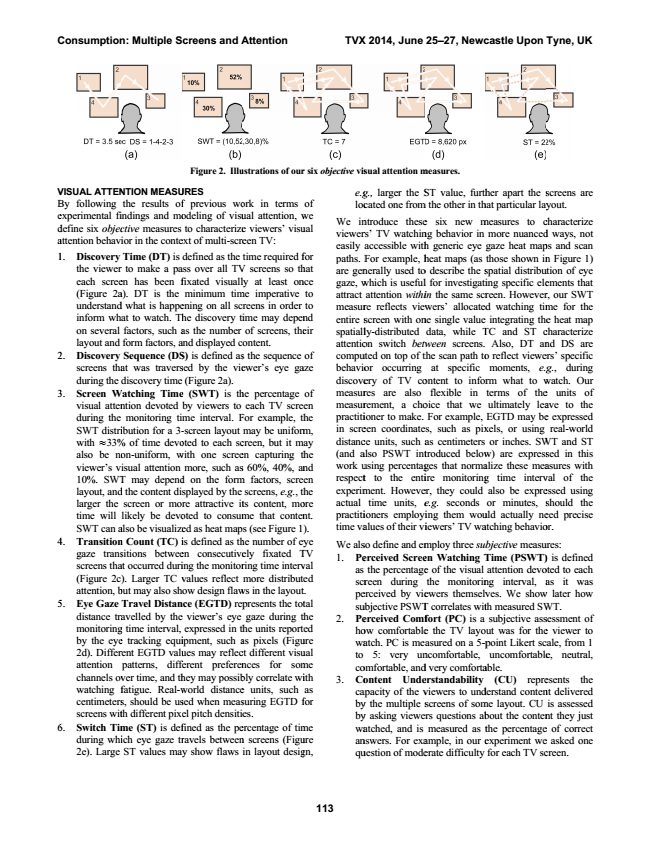
Visual attention Attention is the cognitive process to selectively interpret information subsets while ignoring others, i.e., to selectively

and identified monitoring looks less than 1.5 seconds, orienting looks up to 5 seconds, engaged looks between 6 and 15 seconds, and staring after 15 seconds. focus on solely one aspect of the environment [1] (p. 519). By definition, attention allows people to focus on a single task at one given time. Sohlberg and Mateer [21] identified five levels of attention, which are focused, sustained, selective, alternating, and divided attention.

To characterize visual attention, researchers have employed eye tracking devices that accurately follow viewers’ eye gaze. For example, Kallenbach et al. [12] used an eye tracker and found that text displayed on TV affects the patterns of visual attention, memory, and cognitive workload more than Visual attention has been modeled by cognitive psychologists with the spotlight [5] and zoom-lens models [6]. The spotlight model describes attention in terms of focus (i.e., the region from which information is extracted and processed at high resolution), fringe (i.e., the low-resolution extraction of information at the boundaries of the focus region), and margin (the cut-off of the visual attention area). The zoom- lens model [6] upgraded the spotlight model by making it adaptable in size, and thus explained the trade-off in efficiency of processing visual information, e.g., larger the focus, slower the processing will be.

Researchers have also modeled the way the brain attends to stimuli and processes information in what is known as

simple pictorial information does. Holmes et al. [11] examined the visual attention of people watching TV in a secondary-screen scenario and reported that 30% of the attention was allocated to the tablet. In a multi-screen sports study, Cummins et al. [3] found visual attention to vary function of screen size, game play (i.e., action), and repeated exposure. They also reported that viewers had to adopt screen watching strategies to cope with the many pictures displayed simultaneously. Finally, Rashid et al. [17] identified five factors that affect visual attention patterns for multi-display user interfaces, namely display contiguity, angular coverage, content coordination, input directness, and input-display correspondence.



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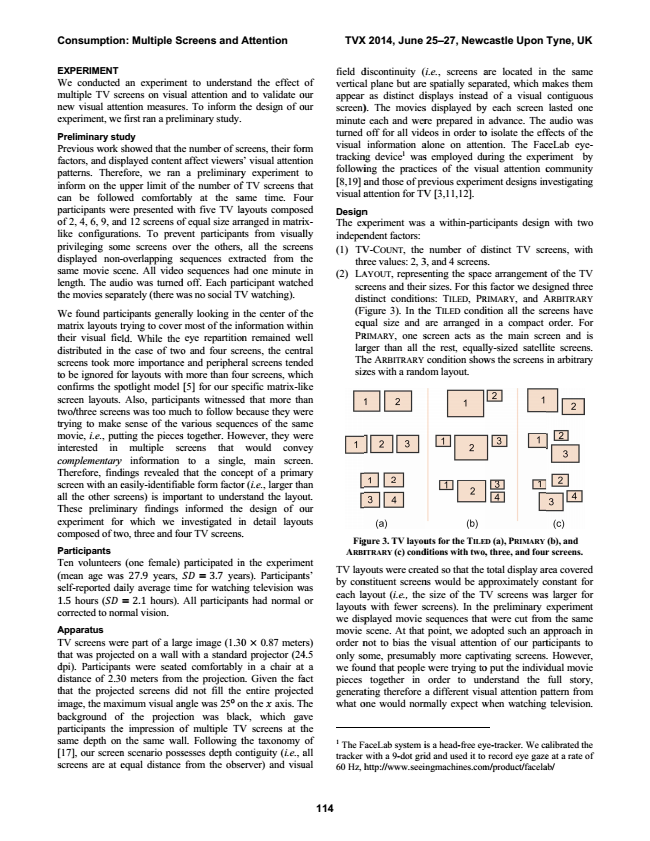
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For the full experiment, the TV screens displayed different

TILED layout, 10/10 for PRIMARY, and 9/10 for ARBITRARY. content. However, we verified the content a priori by

(For convenience, screen numbers are shown in Figure 3.) running a motion detector (frame-to-frame difference) to

For three screens, there are 3! = 6 possible sequences, out of make sure that the motion level was roughly the same across

which 2,3,1 occurred the most for T

ILED screens of the same layout.

Task Participants were asked to watch prerecorded movies for each combination of TV-C

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**115**

(5 out of 10), 2,1,3 for P

RIMARY

(7/10), and no majority preference could be identified for A

RBITRARY

. For four screens, there are 4! = 24 possible sequences, out of which 1,2,4,3 occurred and L

AYOUT

conditions, resulting in a total number of 9 experimental trials per participant corresponding to 9 minutes of watching TV (one minute per condition). Each participant watched the movies separately to eliminate any effect of social watching on attention. Participants were asked to watch the movies as if they were watching their TV at home, and were told they had to answer a questionnaire after each trial in order to ensure a minimal level of attention. Condition order was randomized

the most for T

ILED

(4/10), 2,1,3,4 for P

RIMARY

(4/10) and, again, no majority preference for ARBITRARY (for which 8 different sequences were found among the 10 recordings). These results show that viewers discover screens from left to right for the two screen condition (sequence 1,2), are first attracted by the middle screen when three screens are present (sequences 2,3,1 and 2,1,3), and follow a counter-clockwise pattern (e.g., 1,2,4,3) in the absence of a primary screen to attract attention first (2,1,3,4 for P

RIMARY across participants. After each trial, participants were administered NASA TLX tests2 (using the computer version available on-line at3) to collect workload subjective ratings, and were handed questionnaires to evaluate their understanding of the content they had just watched. At the end of the experiment, participants filled a final questionnaire in which they reported the perceived comfortability (PC) of watching each layout on a 5-point Likert scale, with 1 being very uncomfortable and 5 very comfortable. Participants were also asked to specify the maximum number of TV screens they would feel comfortable watching at the same time (MAX-TV).

RESULTS #1: DISTRIBUTION OF VISUAL ATTENTION FOR MULTI-SCREEN TV Discovery Time Our participants systematically discovered all screens before committing to one screen to watch. In general, this process can be very fast and a single eye fixation is usually enough to roughly understanding the topic being watched [15]. Discovery time varied between 0.1 and 15.5 seconds, with a mean time of 2.4 seconds ( = 0.3). We found a significant effect of TV-COUNT on discovery time ( (2) = 43.400, < .001) showing that more time was needed by participants to visually fixate more screens until all have been discovered (Figure 4a). DT values ranged from 0.8 seconds for two screens up to 4.5 seconds for four screens. A second degree polynomial showed a perfect fit with observed data ( = 1), suggesting that discovery time relates to the number of screens in a quadratic manner (DT = 0.70 ∙ TV-C

OUNT

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The discovery sequence mainly shows the impact of layout. For screens of equal size, a left-to-right model was adopted by our participants, which corresponds to the reading order in Western culture (which was the case for our participants). For the PRIMARY layouts, discovery begins with the larger screen despite it not being the left-most screen. This finding shows that participants immediately identified the largest screen as the main or primary one. The anti-clockwise pattern is also interesting, as it builds on the observed left-to-right model, but also exploits the shortest distance between screens. Consequently, it may represent an instance of the Z- shaped pattern observed during reading [18], but specific for multi-screen TV.

Screen Watching Time The average percentages of visual attention shared between screens are illustrated in Figure 4e using color codes, with darker values showing more visual attention. We found significant differences for the T

ILED

layouts and three and four screens, while only the ARBITRARY layout had a significant effect on SWT for two screens. Results show that screen watching time is related to the size of the screen (i.e., the large screen in all the PRIMARY conditions received more visual attention), but also with content, as we later found by asking participants (e.g., participants’ visual attention was more attracted by the right screen of the 2- A

RBITRARY

and P

RIMARY

condition that displayed a bicycle race, instead by the first screen that showed news, resulting in 68% and 31% devoted attention, see Figure 4e).

− 0.97 ∙ TV-C

OUNT

+1.10). There was no significant effect of LAYOUT on DT ( (2) = 2.867, . .).

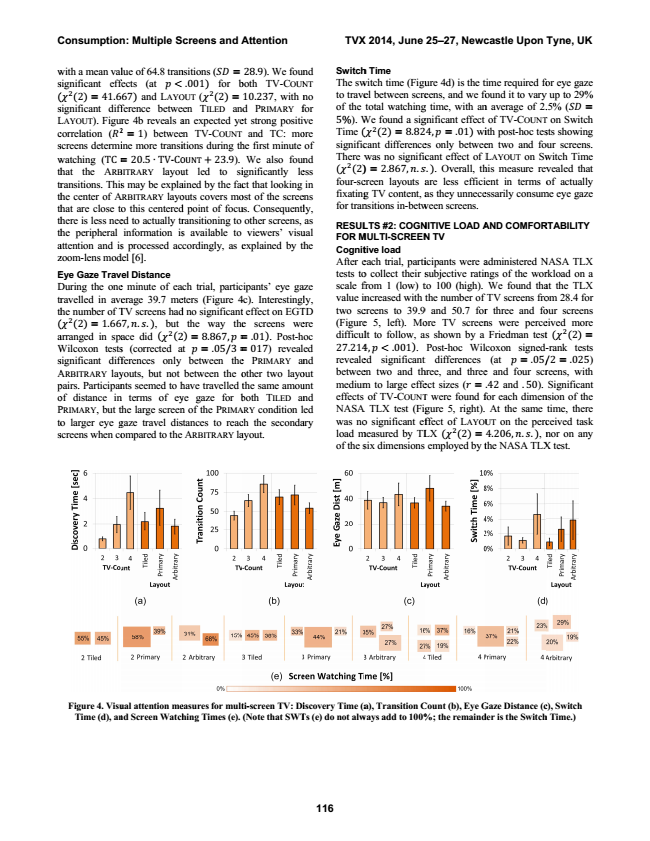
SWT can be further visualized as heat maps (Figure 1) that use color codes to describe gaze density spatially along the screen area size. When all screens are of equal size, the gaze Discovery Sequence The discovery sequence informs about the order in which screens are visually attended during the discovery time. For two screens, there are only two possible sequences, i.e., 1,2 and 2,1, and we found our participants preferring the former for all layouts, with preference counts of 8 out of 10 for the

density reflects the SWT values exactly (e.g., low color density for the first screen, larger for the central, and moderate for the third in the 3-TILED condition, see both Figures 1 and 4e). However, in the PRIMARY condition, the gaze density color of the largest screen has lower maxima, as gaze is distributed across a larger area (larger coverage).

Transition Count 2 http://humansystems.arc.nasa.gov/groups/tlx/

The number of eye gaze transitions between screens varied 3 http://www.keithv.com/software/nasatlx/

from 11 to 200 for the entire watching time of one minute,



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w with a mean val s significant eff ( ( (2) = 41.6 s significant diff L LAYOUT). Figur c correlation ( s screens determi w watching (TC = th

hat the A

RB tr

ransitions. This th

he center of A th

hat are close to th

here is less nee th

he peripheral a attention and is z zoom-lens mod

E Eye Gaze Trav D During the one tr

ravelled in ave th

he number of T ( ( (2) = 1.66 a arranged in spa W Wilcoxon tests s significant diff A A

RBITRARY

lay p pairs. Participan o of distance in P P

RIMARY

, but t to

o larger eye g s screens when co

**Figure 4. Visu Time (d), an**

**116**

lue of 64.8 tran fects (at <

67) and LAYO ference betwe re 4b reveals a = 1) betwee ine more transi = 20.5 ∙ TV-C

O BITRARY

layou s may be expla A

RBITRARY

layo o this centered ed to actually tr information is s processed ac del [6].

el Distance e minute of ea erage 39.7 me TV screens had 7, . .), but ace did ( (2 s (corrected a fferences only youts, but not nts seemed to h n terms of ey the large screen gaze travel dis ompared to the

**ual attention me nd Screen Watch**

nsitions ( =

.001) for b OUT ( (2) = een TILED and an expected ye en TV-COUNT itions during th OUNT

+ 23.9). ut led to si ained by the fac outs covers mo d point of focu ransitioning to s available to cordingly, as e

ach trial, partic eters (Figure 4 d no significant

the way the 2) = 8.867, = at = .05/3 =

between the between the o have travelled t ye gaze for b n of the P

RIMA stances to reac ARBITRARY la

**easures for mult hing Times (e).**

28.9). We foun both TV-COUN 10.237, with n d PRIMARY f et strong positiv

and TC: mo he first minute

We also foun ignificantly le ct that looking ost of the scree us. Consequentl other screens,

viewers’ visu explained by th

ipants’ eye ga 4c). Interestingl t effect on EGT e screens we = .01). Post-h = 017) reveal e PRIMARY an other two layo the same amou both T

ILED

an ARY

condition l ch the seconda ayout.

**ti-screen TV: Di (Note that SWT**

**Switch nd NT**

The sw no for

to trave of the ve ore

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signific There w ( (2) four-sc fixating for tran as ual he

RESUL FOR M Cognit After e tests to aze

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(Figure oc

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NASA ary

was no load m of the s

**iscovery Time (a Ts (e) do not alw**

h Time witch time (Figu el between scre total watching We found a sig ( (2) = 8.82 cant difference was no signific ) = 2.867, . creen layouts a g TV content, a nsitions in-betw

**LTS #2: COGN MULTI-SCREEN**

tive load each trial, parti o collect their s from 1 (low) t increased with creens to 39.9 e 5, left). Mo lt to follow, a 4, < .001). ed significant en two and th m to large effe

of TV-C

OUNT A TLX test (Fig o significant ef measured by TL six dimensions

**a), Transition C ways add to 100%**

ure 4d) is the t eens, and we fo g time, with an gnificant effect

4, = .01) wi es only betwee

cant effect of L .). Overall, th are less effici as they unnece ween screens.

**NITIVE LOAD A**

**N TV**

icipants were a subjective ratin to 100 (high). the number of 9 and 50.7 for ore TV screen as shown by a Post-hoc Wil t differences hree, and three ect sizes ( = T

were found f gure 5, right). ffect of L

AYOU LX ( (2) =

employed by t

**Count (b), Eye G %; the remaind**

time required fo found it to vary n average of 2. of TV-COUNT ith post-hoc tes en two and fo L

AYOUT

on Sw his measure rev ent in terms o essarily consum

**AND COMFOR**

administered N ngs of the wor We found tha TV screens fro r three and fo ns were perce Friedman test coxon signed- (at = .05/ e and four scr .42 and .50). for each dimen At the same UT

on the perc 4.206, . .), n the NASA TLX

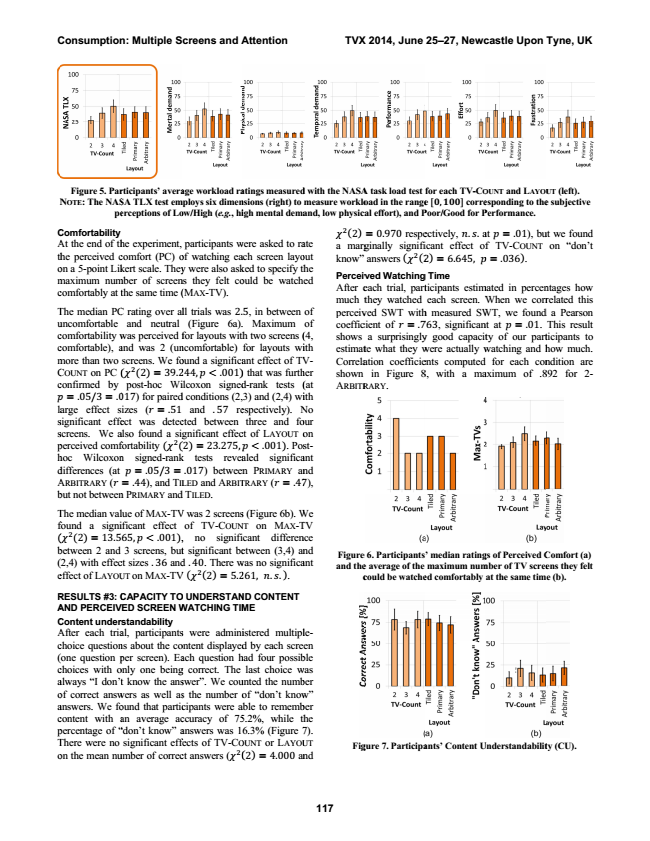
**Gaze Distance (c der is the Switch**

or eye gaze y up to 29% .5% ( = T on Switch sts showing our screens. witch Time vealed that of actually me eye gaze

**RTABILITY**

NASA TLX rkload on a at the TLX om 28.4 for our screens eived more t ( (2) = -rank tests /2 = .025) reens, with Significant nsion of the time, there ceived task nor on any X test.

**c), Switch h Time.)**



**N**

C A th o m c

T u c c m C c

la s s p h d A b

T f ( b ( e

R A C A c ( c a o a c p T o

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**Figure 5. Par N**

**OTE**

**: The NAS pe**

Comfortability At the end of th he perceived c on a 5-point Lik maximum num comfortably at t

The median PC uncomfortable comfortability w comfortable), a more than two COUNT on PC ( confirmed by

= .05/3 = .0 arge effect s significant effe screens. We a perceived comf hoc Wilcoxon differences (at ARBITRARY ( but not between

The median val found a signi ( (2) = 13.5 between 2 and (2,4) with effec effect of LAYOU

RESULTS #3: C AND PERCEIV Content under After each tria choice question (one question p choices with o always “I don’t of correct answ answers. We fo content with a percentage of “ There were no on the mean nu

**117**

**rticipants’ avera SA TLX test em erceptions of Lo**

he experiment, comfort (PC) o kert scale. They mber of screen the same time (

C rating over al

and neutral was perceived f and was 2 (un screens. We fo ( (2) = 39.2 post-hoc Wi 017) for paired izes ( = .51 ect was detec also found a si fortability ( ( n signed-rank

= .05/3 = = .44), and TIL n PRIMARY and

lue of MAX-TV ificant effect

65, < .001), 3 screens, but ct sizes .36 and UT on MAX-TV

**CAPACITY TO VED SCREEN W**

rstandability al, participants ns about the co per screen). Ea only one being t know the ans wers as well as ound that partic an average ac “don’t know” a significant eff umber of correc

**age workload ra mploys six dimen ow/High (e.g., hi**

participants w of watching ea y were also ask ns they felt co

(M

AX

-TV).

ll trials was 2. (Figure 6a). for layouts with ncomfortable) ound a significa 244, < .001) ilcoxon signed d conditions (2, and .57 re cted between

gnificant effec (2) = 23.275, k tests revea .017) between LED and ARBIT d TILED.

V was 2 screens of TV-COUN , no signifi t significant be d .40. There w V ( (2) = 5.2

**O UNDERSTAN**

**WATCHING TIM**

s were admini ontent displayed ach question h g correct. The swer”. We cou s the number o cipants were a ccuracy of 75 answers was 1 fects of TV-CO ct answers ( (

**atings measured nsions (right) to**

**igh mental dema**

were asked to ra ach screen layo ked to specify th ould be watch

5, in between Maximum h two screens ( for layouts wi ant effect of TV ) that was furth d-rank tests ( 3) and (2,4) wi espectively). N three and fo ct of L

AYOUT

o < .001). Pos aled significa n PRIMARY an TRARY ( = .47

s (Figure 6b). W NT on MAX-T cant differen etween (3,4) an was no significa 261, . .).

**ND CONTENT**

**ME**

istered multipl d by each scre had four possib last choice w unted the numb

of “don’t know able to rememb 5.2%, while th 6.3% (Figure 7 OUNT or LAYOU (2) = 4.000 an

**d with the NASA measure worklo and, low physic**

ate out he ed

of of (4, ith V- her (at ith No our on st- ant nd 7),

We TV nce nd ant

le- en ble was ber w” ber he 7). UT nd

(2) a marg know”

Perceiv After e much t perceiv coeffic shows estimat Correla shown ARBITR

**Figure and the c**

**Fig**

**A task load test**

**oad in the range cal effort), and P**

= 0.970 respe ginally signifi

answers ( (2

ved Watching each trial, part they watched ved SWT with cient of = .7 a surprisingly te what they w ation coefficie in Figure 8 RARY.

**e 6. Participants e average of the could be watche**

**gure 7. Participa**

**for each TV-C**

**O e , corre Poor/Good for P**

ectively, . . a icant effect of 2) = 6.645,

**g Time**

ticipants estim

each screen. W h measured SW 763, significan y good capacit were actually w ents computed 8, with a ma

**’ median rating maximum num ed comfortably**

**ants’ Content U**

**and OUNT**

**L**

**AYOU esponding to the Performance.**

at = .01), bu

f TV-C

OUNT = .036).

mated in percen When we corr WT, we found nt at = .01.

ty of our part watching and h for each con aximum of .8

**gs of Perceived C mber of TV scree at the same tim**

**Understandabilit**

**(left). UT e subjective**

ut we found on “don’t

ntages how related this d a Pearson This result ticipants to how much. ndition are 892 for 2-

**Comfort (a) ens they felt e (b).**

**ty (CU).**



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**Figure 8. Corre (All signific**

V VISUAL ATTEN W We release our A Attention Tool a available to t c companion to d downloaded fro a also release all a and eye gaze tr s study as a mu r replication of r v visual attention C CONCLUSION W We proposed in m measures to cha m multi-screen TV b be computed a th

he paper. We a T TV layouts and s structure affect W We look forwar b by the commun a attention pattern

A ACKNOWLEDG T The paper and E European Com e elastic Platform m multimedia”, ref

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**elations between cant at = .**

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this paper con om http://ww the data files racking data lo ulti-screen eye results and enc phenomena fo

n this work a s aracterize view V, out of which automatically w applied our me d showed how t viewers’ visua rd to see how o nity to understa ns for emerging

**GEMENTS**

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**measured SWT A**

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