Validation study for selected psychometric ERTS tests

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Structure of test battery

The test battery applied in this study was assembled out of a pool of ERTS-sub tests each of those aiming to measure a specific cognitive performance. All sub-tests originate from classic, well-proven cognitive paradigms that are well understand and many times replicated in psychological and pharmaco-psychological research or from tasks that are typically applied within the context of pharmaceutical drug studies (Digit Symbol Substitution Task).

The test battery has been configured to cover several distinct cognitive processes and different levels of complexity (Gaillard, 1988):

- Structural aspects such as Sensoric vs. Central vs. Motoric
- Energetic aspects such as Simple vs. Complex tasks,
- Specific higher mental concepts such as mathematical processing, spatial processing, working memory load.

Table 1 lists sub-tests according to those dimensions. For a description of each sub-text see appendix A.

	Complex	**Simple**
Sensoric		
Visual Encoding	DIGRT: Stimulus Quality	
Occulo-motoric	DIGRT: Position of Stimulus	
Stimulus intensity		SRT
Occulo-motoric	VSDIG: Similar Targets	
Pop-Out of peripheral information	VSDIG: Dissimilar Targets	
Central		
Continuous Performance	DSST	
Mathematical processing	MATH	
Spatial Processing	MROTAT	
Working Memory	STERN: Set Size Effect	
Choice Reaction	STERN: Additive effect	
Sustained attention		CLOCK
Motoric		
Continuous psychomotoric	TRACK	
self-initiated		TAPP

Table 1 gives an overview about all tests included in the battery.

The sensoric tests contain conditions that are potentially sensitive to impairments of the occulo-motoric system (VSDIG and DIGRT-Position) and visual information processing (DIGRT-Quality).

Tests related to higher mental processes have been designed to measure different cognitive concepts like spatial processing (MROTAT) or mathematical processing (MATH) and to induce heavy working memory load (DSST, MATH), varying working memory load (STERN-Slope), or no working memory load (MROTAT).

Tasks of different complexity have been included to make the battery more sensitive to possible pharmaco-effects that are due to different states of general arousal. Differences in arousal may be more likely reflected by simple tasks that are less motivating than by tasks that are high demanding.

To obtain estimates of motoric performance a continuous compensatory tracking task has been included (TRACK) and tapping at maximum speed (TAPP).

Results

Appendix B lists all dependent variables together with their basic effects, their estimated re-test reliability, and the significance of drug effects derived from ANCOVA. All basic effects are in line with results known from general psychological research.

Re-test reliability

Re-test reliability has been computed for the placebo group only (N=10). With few exceptions (DIGRT, CLOCK, RMS) re-test reliability is within a very satisfactory range for cognitive tests.

Low re-test reliability of differences between two conditions within the DIGRT are partly expected from statistical theory because the difference of two values is always less reliable than the each value. Test results show no pharmaco-related effect except an interaction Stimulus-Position x Stimulus Quality x Dose. The pattern of the interaction, however, cannot be interpreted in a meaningful way.

The low reliability in the clock test might has two reasons. First, the tables lists the split values between first and second 10 min periods. Estimates across the entire test period of 20 minutes are more stable (.43, .41 for A' and .67, 72 for M(Hit). Second, as this test highly reflects the current state of activation test performance depends on the subject's daily form more than in other cognitive tasks.

.The low reliability in tracking performance seems to be due to the small sample size because it becomes much better when values from all subjects are included (.80, .70).

Drug-effects

For testing drug effects performance data from the reference sessions have been used as a covariate in the ANOVA. The ANCOVA for day 1 compares only placebo vs. verum because the dose of 50mg was identical for all groups. The ANCOVA for Day 10 uses dose as a four level factor (placebo, 50mg, 100mg, 150mg).

Day 1

Significant ($p < .05$) drug-related effects on day 1 have been found for

TAPP-N	p(F=9.21, df 1,34) = .0046	Number of tapps within one minute
SRT-MeanRt	p(F=6.92, df 1,35) = .0126	Mean latency of Simple Reaction
DSST-Mem	p(F=5.97, df 1,35) = .0197	Number of memorized digit-symbol assignments,
MATH	p(F=4.40, df 1,35) = .0436	Speed of solving 3-digit add/sub tasks.

Day 10

Significant ($p < .05$) dose-related effects on day 10 have been found for

CLOCK-M(Hit)	p(F=5.46, df 1,35) = .0253	Mean latency for hits during 20 minutes
CLOCK-A'	p(F=5.02, df 1,34) = .0314	Signal discrimination during 20 minutes
TAPP-N	p(F=4.76, df 1,35) = .0359	Number of tapps within one minute
SRT-MeanRt	p(F=4.58, df 1,35) = .0393	Mean latency of Simple Reaction
STERN-Error	p(F=4.14, df 1,34) = .0498	Percent error in memory search

Factor analysis

A rotated factor analysis with direct Oblimin rotation was performed with the most important dependent variables in order to derive number and content of independent factors that are covered by the entire test-battery. (see Appendix C for details). Factor analysis has been performed separately for day 1 and day 10. Some redundant statistics have been removed to lower the number of variables included in the analysis.

For day 1 the following factors have been derived:

Factor	Eigenvalue	Pct of Var	Cum Pct	Meaning
1	4,04237	25,3	25,3	**Cognitive speed at complex tasks**
2	1,95182	12,2	37,5	**Psychomotoric performance:**
3	1,62501	10,2	47,6	**Sensoric processes**
4	1,51970	9,5	57,1	**Speed at simple tasks**
5	1,23017	7,7	64,8	**Vigilance and general arousal**
6	1,11060	6,9	71,7	**Working memory**

For day 10 the following factors have been derived:

Factor	Eigenvalue	Pct of Var	Cum Pct	Meaning
1	4,32445	27,0	27,0	**Cognitive speed at complex tasks**
2	2,08607	13,0	40,1	**Speed at simple tasks and stimulus position effect**
3	1,74866	10,9	51,0	**Working memory and vigilance**
4	1,57842	9,9	60,9	**Psychomotoric performance**
5	1,18177	7,4	68,2	**Sensoric processes**
6	1,07314	6,7	75,0	**General Arousal**

Both factor analysis revealed a factor representing cognitive speed at complex tasks. This is a very common result for cognitive test batteries. There have been almost no drug observed effects on this factor.

MeanRts in the Simple Reaction Time Test and in the Clock Test build another factor representing response latencies in tasks that are simple and do not allow for any response preparation. This factor is related to observed pharmaco effects.

Performance in memory search, mathematical processing, Memory in digit symbol substitution test are grouped more or less within one factor. This factor must be interpreted as representing a working memory component. Some pharmaco-effects are observed in this factor.

On day 10, signal discriminability in the Clock Test loads on this factor as well, but for day 1 it builds a separate factor together with tapping. Thus, performance in the clock task seems to be related to general arousal and working memory. This factor is most significantly influenced by drug effects.

Although Tracking and Tapping performance do moderately correlate, they are assigned to two different factors each one standing for this particular test paradigm.

The sensoric test parameters do not build a very salient and stable factor and seem not to be related to dose effects.

Because there is a considerable overlap of factor loadings, an alternative method has been used to visualize the correlation matrix of all dependent variables (see appendix D). Based on the correlation matrix, undirected graphs have been derived by using the pathfinder technique. This algorithm derives a network solution from similarity data, which has a minimum number of links between nodes. The spatial layout of nodes should corresponds to similarity data.

Appendix A: Description of sub-tests

Test	Test Paradigm	Concept	Reference	Stimulus Material	Design	Task
TAPP:	Tapping with max speed	General motoric state	Kleindienst-Vanderbeke, G., & Irmisch, R. (1988). Volz, H.-P. & Sturm, Y. (1992).	-	1 minute test period	Press the key as fast as possible for 1 minute
MROTAT	Mental Rotation	Spatial processing	Cooper, L.A. & Shepard, L.N. (1973).	Normal or mirrored symbols {F, G, J, R, F, 2, 4, 5, 7} in 0° and 180° orientiation	8 warm-up and 64 valid trials, UVs: Angles(0°, 180°) x Mirrored(Yes/No),	Decide whether the digit is e regular or a mirrored digit.
MATH	Mathematical Processing (AGARD version)	Mathematical processing	Restle, F. (1970). Shingledecker, C.A. (1984). Schlegel, R.E. & Gilland, K. (1987). Repko, J.D., Jones, P.E., Garcia, L.S., Schneider, E.J., & Corum, C.R. (1976).	3 digit addition/subtraction tasks with intermediate and final results in the range of 1-10	5 warm-up trials with Feedback and 180s test period	Decide whether the result is lower or greater than 5
SRT	Simple Reaction to red flash that appears at random intervals	Basic information processing speed	Donders, F.C. (1969). Pachella, R.G. (????)	A red square of about 5cm x 5cm size appearing at random intervals	10 warm-up and 40 valid trials	Press a key as fast as possible whenever a red square appears on the screen
DIGRT	Choice reaction with normal vs. degraded stimuli with centered vs. peripheral stimulus locations	Test of peripheral impairments in visual encoding and saccadic eye movement	Boer, L.C. & Gaillard, A.W.K. (unpublished paper from 1986). AGARD (1989).	Normal Digits {2,3,4,5} or one of 4 degraded versions for each digit displayed in the center or in one of the four corner of the monitor	8 warm-up and 128 valid trials, UVs: Location(Center vs. Corner) x Quality(Normal, Degraded)	Press the left key whenever you see one the digits {2,3}, press right key if you see the digits {4,5}
VSDIG	Visual search with high vs. low target/distractor similarity	Serial and parallel scanning of visual objects	Schneider, W. & Shiffrin, R.M. (1977). Mohr, W. (1984). Beringer, J., Wandmacher, J., & Gärtelmeyer, R. (1988)	Targets {2,3,5,6,9} among either similar distractors {mirrored 2,3, 5, 6, 9}, or dissimilar distractors (N,K,V,X,Y)	8 warm-up and 80 valid trials, UVs: Target(Yes, No) x Similarity(High, Low)	Press the right key if you detect a regular digit among letters or mirrored digits. Press the left key, if you do not see a regular digit

Test	Test Paradigm	Concept	Reference	Stimulus Material	Design	Task
			Görtelmeyer, R. (1988).	{N,K,V,X,Y}		not see a regular digit
CLOCK	Clock Test	Sustained attention	Parasuraman & Davies (1984).	Marker moving on 80 positions around a circle with a diameter of 12cm. In 6% (6 among each 100 events) one position was skipped	20 min test period (800 trials) with signal probality of 6% within each 100 trials. 1,5s presentation rate: 500 ms marker on, 1000ms marker off time.	Press a key whenever the marker on the clock skips one position
DSST	Computerized Digit Symbol Substitution Test	Continuous Performance under high mental processing load		Digits {1,2,3,4} assigned at random to 8 symbols (8 to 4 mapping). Mapping table was present during test period, not present at recognition block	3min test period followed by 8 trials with each symbol as recognition test	Translate geometric figure into digit and press corresponding key.
TRACK	Unstable tracking task with disturbance	Continuous psychomotoric regulation	Jex, H.R., McDonnell, J.D., and Phatak, A.V. (1966). Poulton, E.C. (1974). AGARD (1989). Manzey, D., Lorenz, B., Schiewe, A., Finell, G. & Thiele, G. (1993).	Bar with unstable characteristic: Instability 200 (Lambda) plus random disturbance (max Amplitude 2cm, Filter 0.3Hz)	10s warm-up and 5min test period.	Keep the bar as close as possible in the middle of the screen
STERN	Sternberg memory search with variable search set	Working memory scanning	Sternberg, S. (1966). Leonard, J.P., Ahlstich, S., & Beringer, J. (in preparation).	Memory search sets consisting of two or five digits {0,1,2,3,4,5,6,7,9}	4 warm-up trials and 80 valid trials. SetSize(2: 2/5) x Probe(2: Positive/Negative):	Press right key, if the probe digit was within the previously shown search set. Press left key if not.

Appendix B: Dependent variables

This table describes the most meaningful dependent variables of each sub-test and gives an overview about general effects (Mean in reference, re-test reliability, ANCOVA drug-effects

Test Dependent Variable	Description	N Obser-vations	Baseline results	24 Hours re-test (placebo)	10 days re-test (placebo)	Day 1 p(F)	Day 10 p(F)
TAPP							
N(presses)	Number of Tapps within 1 minute	1 min	396 Taps	.97	.81	**.005** ***	**.036** **
Stdv(presses)	Standard deviation of InterPressIntervals					.308	.958
MROTAT							
RtC(0°)	Mean correct reaction time to 0° orientation	32	1054 ms	.85	.81	.073 *	.092 *
RtC(180°)	Mean correct reaction time to 180° orientation	32	1744 ms	.83	.93	.140 +	.722
MATH							
RtC	Mean correct reaction time	3 min	2203 ms	.90	.92	**.044** **	.274
SRT							
RtC	Mean simple reaction time	40	248 ms	.90	.91	**.013** **	**.039** **
DIGRT							
DiffRtC(Quality)	Difference between correct reactions to degraded minus normal digits	32	107 ms	.36	-.15	.560	.366
DiffRtC(Position)	Difference between correct reactions to peripheral minus centered digits	32	96 ms	-.33	.12	.472	.261
VSDIG							
RtC(Similar)	Mean correct reaction time in search sets with similar distractors	40	3807 ms	.59	.87	.202 +	.570
RtC(Dissimilar)	Mean correct reaction time in search sets with dissimilar distractors	40	861 ms	.86	.69	.976	.066 *
PE(Similar)	Percent errors in search sets with similar distractors		0.06		.16	.122 +	.167 +
PE(Dissimilar)	Percent errors in search sets with dissimilar distractors		7.19	.43	-.24	.105 +	.894
CLOCK							
A'(1-10)	A' (SDT discrimination index) for first 10 minutes	400	.993	.01	.49	.410	.090 *
A'(11-20)	A' (SDT discrimination index) for second 10 minutes	400	.989	.46	.73	.539	**.030** **
RtHit(1-10)	Mean correct reaction time (Hits) first 10 minutes	24	498 ms	.72	.51	.140 +	**.025** **

Test Dependent Variable	Description	N Obser-vations	Baseline results	24 Hours re-test (placebo)	10 days re-test (placebo)	Day 1 p(F)	Day 10 p(F)
RtHit(11-20)	Mean correct reaction time (Hits) second 10 minutes Performance is measured in terms of signal detection theory: Discimination index $A' = 1 - \frac{1}{4} \cdot \left(\frac{p[FA]}{p[Hit]} + \frac{1 - p[Hit]}{1 - p[FA]} \right)$	24	521 ms	.18	.36	.067 *	.052 *
DSST							
RtC	Mean correct reaction time	3 min	1749 ms	.73	.78	.053 *	.893
NC(Recognized)	Number of correctly assigned digit/symbol pairs (max 8)		7.27			**.020 ** **	.636
TRACK							
RMS	Root mean squared error (deviation of bar)	5 min	7.14	.75	.19	.441	.284
Error	Number of loss of controls (bounces against boarders)		.05		-.11	.472	.789
	Root mean squared error $RMS = \sqrt{\frac{\sum BarPos^2}{n}}$						
STERN							
Height	Intercept of linear Rt function of SetSize	40	496 ms	.89	.64	.924	.167 +
Slope	Slope of linear Rt function of SetSize	40	87 ms	.92	.82	.255	.729
PE	Percent error					.123 +	**.050 ** **

*** means p(F) ≤ .01, ** means p(F) ≤ .05, * means p(F) ≤ .10, + means F ≥ 1.5

Appendix C: Factor-Analysis

Factor-Analysis on day 1

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
		*				
ASB4	1,00000	*	1	4,04237	25,3	25,3
DCDG4	1,00000	*	2	1,95182	12,2	37,5
DCPO4	1,00000	*	3	1,62501	10,2	47,6
ERR4	1,00000	*	4	1,51970	9,5	57,1
H4	1,00000	*	5	1,23017	7,7	64,8
MC180T4	1,00000	*	6	1,11060	6,9	71,7
MCDSS4	1,00000	*	7	,89196	5,6	77,3
MCMAT4	1,00000	*	8	,78205	4,9	82,2
MCS4	1,00000	*	9	,62001	3,9	86,1
MCSRT4	1,00000	*	10	,48771	3,0	89,1
MHB4	1,00000	*	11	,48013	3,0	92,1
NCREC4	1,00000	*	12	,39424	2,5	94,6
RMS4	1,00000	*	13	,32652	2,0	96,6
S4	1,00000	*	14	,27277	1,7	98,3
TAPN4	1,00000	*	15	,14969	,9	99,3
MCD4	1,00000	*	16	,11525	,7	100,0

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
Cognitive Speed at complex tasks								
MROTAT	Rt(180)	,83580	,20214	,21864	,16770	-,10552	-,06930	+
STERN	Height	,78126	-,16011	-,04878	-,21179	-,01241	,30589	
VSDIG	Dissim	,75540	-,02129	-,13804	-,13110	,09681	-,28329	
DSST	Rt	,59307	-,23856	-,50710	,08495	-,16059	-,12890	
Psychomotoric performance:								
TRACK	Error	,12052	-,84455	,08022	,17890	,08863	,13098	
TRACK	Rms	-,14842	-,71103	,03871	-,30914	-,09441	,00998	
Sensoric processes								
DIGRT	Pos	,05375	,23758	-,74370	,03351	,35507	,05654	
DIGRT	Qual	-,13251	-,02319	-,55284	-,27513	-,24883	-,22671	
Speed at simple tasks								
SRT	Rt	-,01744	-,11229	,12410	-,84253	-,06460	,08617	**
CLOKCK	Rt(b)	-,01766	,05036	-,15471	-,76697	,08259	-,03566	*
VSDIG	Simil	,39479	,19697	,41398	-,44285	,34886	-,20583	+
DSST	NRec	-,33315	,31732	,10646	,34209	,17115	,22715	*
Vigilance and general arousal								
CLOCK	A(b)	-,04355	,02137	-,09591	-,06373	,80561	,11536	
TAPP	N	-,28732	-,31497	,06643	,33900	,48767	-,30693	***
Working memory								
STERN	Slope	-,07199	,21896	-,03247	,04643	-,18796	-,86153	
MATH	Rt	,40386	-,21069	-,01625	-,07699	,25441	-,65782	**

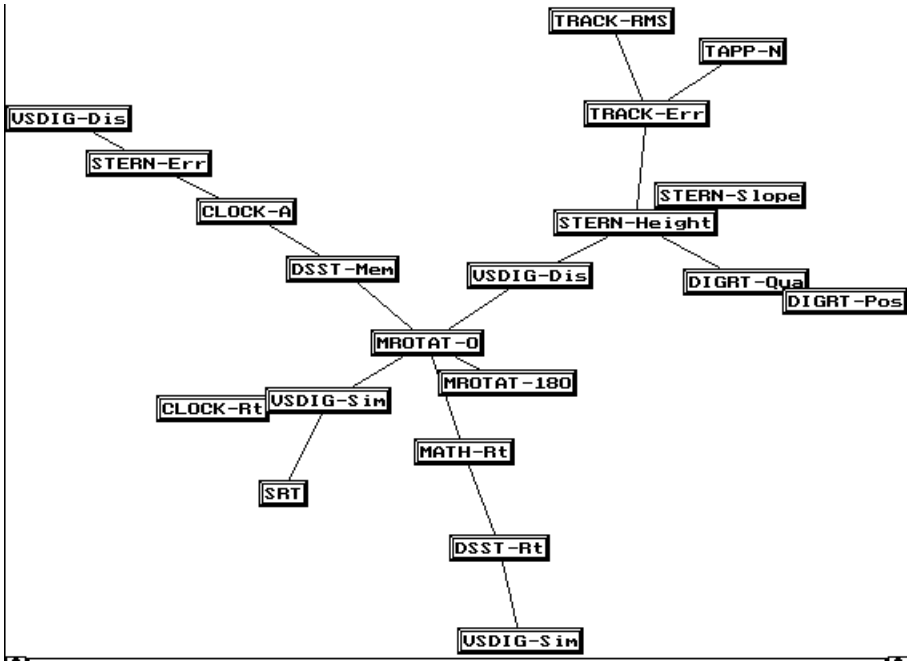
Factor-Analysis on day 10

Variable	Communality	*	Factor	Eigenvalue	Pct of Var	Cum Pct
		*				
ASB5	1,00000	*	1	4,32445	27,0	27,0
DCDG5	1,00000	*	2	2,08607	13,0	40,1
DCPO5	1,00000	*	3	1,74866	10,9	51,0
ERR5	1,00000	*	4	1,57842	9,9	60,9
H5	1,00000	*	5	1,18177	7,4	68,2
MC180T5	1,00000	*	6	1,07314	6,7	75,0
MCDSS5	1,00000	*	7	,80185	5,0	80,0
MCMAT5	1,00000	*	8	,63094	3,9	83,9
MCS5	1,00000	*	9	,55672	3,5	87,4
MCSRT5	1,00000	*	10	,52315	3,3	90,7
MHB5	1,00000	*	11	,37233	2,3	93,0
NCREC5	1,00000	*	12	,33250	2,1	95,1
RMS5	1,00000	*	13	,28464	1,8	96,8
S5	1,00000	*	14	,24216	1,5	98,4
TAPN5	1,00000	*	15	,16580	1,0	99,4
MCD5	1,00000	*	16	,09741	,6	100,0

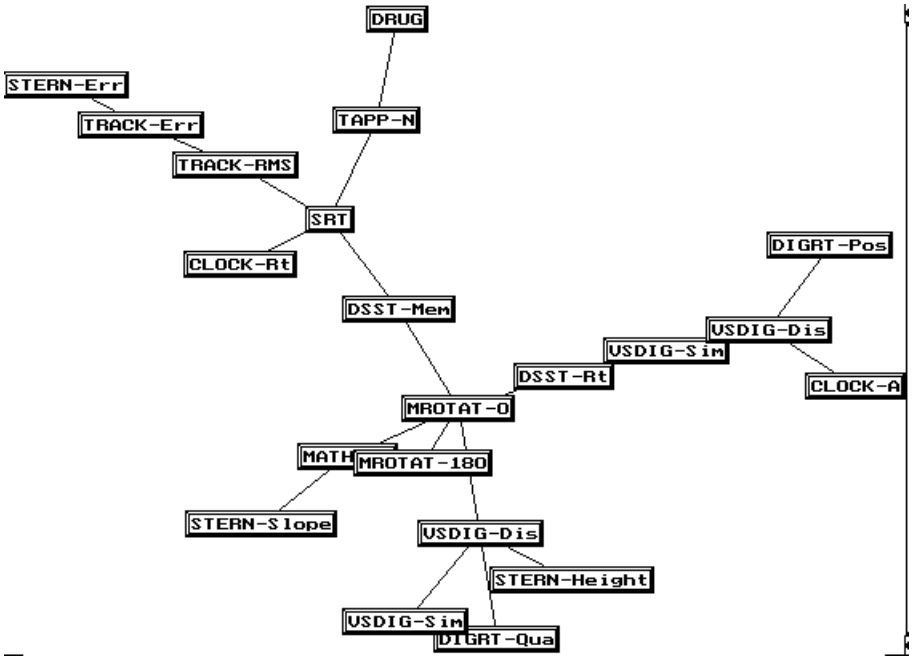
		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
Cognitive speed at complex tasks								
MROTAT	Rt(180)	,90647	,06336	-,00537	-,15296	-,15939	,08125	
VSDIG	**Dissim**	**,72435**	**,01845**	**-,05328**	**,30482**	**,01021**	**-,18089**	*****
MATH	Rt	,69107	,09833	-,16433	,24447	,24600	-,04978	
STERN	Height	,61624	-,43766	,26423	-,02132	-,12351	-,30336	+
DSST	Rt	,47200	,31565	-,29342	,19255	-,04855	-,39320	
Speed at simple tasks and stimulus position effect								
DIGRT	Pos	,05587	,83564	,08091	,18039	,19752	-,03537	
SRT	**Rt**	**,03041**	**-,65122**	**,15160**	**,47740**	**,09689**	**-,13716**	******
CLOCK	**Rt(b)**	**-,06921**	**-,43581**	**-,35980**	**,16883**	**,33721**	**-,29870**	
Working memory and vigilance								
DSST	Nrec	,08536	,07015	,85950	,01277	,14296	-,00475	
STERN	Slope	,22301	,27511	-,69108	,09878	-,05977	-,02718	
CLOCK	**A(b)**	**-,02415**	**,17871**	**,55219**	**,04033**	**-,40819**	**,06959**	******
Psychomotoric performance:								
TRACK	Error	,04795	,16654	,06835	,84222	-,01420	,12046	
TRACK	Rms	-,02204	-,12429	-,13442	,81394	-,07403	,08276	
Sensoric processes								
DIGRT	Qual	,20957	-,33444	-,16089	,03154	-,77961	,08406	
VSDIG	Simil	,45377	-,39023	-,10125	-,13641	,59385	,37052	
General Arousal								
TAPP	**N**	**-,04985**	**,04311**	**,02838**	**,24138**	**-,02716**	**,90133**	*******

Appendix D: Correlation Network

Correlation network for reference session



Correlation network for day 1



Correlation network for day 10