Strictly Embargoed until Wednesday 4th September

Title: Can The QLink Ally (R), A Form Of Sympathetic Resonance Technology (SRT (TM)), Attenuate Acute Mobile Phone Related Changes To Neural Function? A Pilot Study.

Rodney J. Croft[*†], Jody S. Chandler[*], Adrian P. Burgess[‡], Robert J. Barry[*], John D. Williams[¢] & Adam R. Clarke[*].

[*] Brain & Behaviour Research Institute, University of Wollongong, Northfields Ave., Wollongong 2522, Australia

[†] Centre for Neuropsychopharmacology, Swinburne University of Technology, Hawthorn 3122, Australia

[‡] Department of Cognitive Neuroscience & Behaviour, Imperial College Medical School, St. Dunstans Road, London W68RF, U.K.

[¢] Department of Psychology, Coventry University, Priory St., Coventry CV15FB, U.K.

Address correspondence to:

Rodney J. Croft, Centre for Neuropsychopharmacology, Swinburne University of Technology, Hawthorn 3122, Australia. Tel: +61(3)92148769; Fax: +61(3)92145230; Email: rcroft@swin.edu.au

Running head: Attenuation of Mobile Phone Effects on EEG

Key words: Mobile Phone; EMF; Q Link; Resting EEG; ERD.

Objectives: Exposure to active mobile phones (MP) has been shown to affect human neural function in terms of the electroencephalogram (EEG). Although it has not been determined whether such effects are harmful, a number of devices have been developed that attempt to minimise these MP-related effects. One such device, the Q Link Ally® (QL), is argued to affect the human organism in such a way as to attenuate the effect of MPs. The present pilot study was designed to determine whether there is any indication that QL does alter MP-related effects on the human EEG. **Design:** Twenty-four subjects participated in a single-blind, fully counterbalanced cross-over design where subjects' resting EEG and phase-locked neural responses to auditory stimuli were assessed under conditions of either active MP or active MP plus QL. **Results:** The addition of QL to the MP condition increased resting EEG in the gamma range and did so as a function of exposure duration, and it attenuated MP-related effects in the delta and alpha range (at trend-level). The addition of the QL also affected phase-locked neural responses, with a laterality reversal in the alpha range and an alteration to changes over time in the delta range, a reduction of the MP-related beta decrease over time at fronto-posterior sites, and a global reduction in the gamma range that increased as a function of exposure duration. No unambiguous relations were found between these changes and either performance or psychological state. **Conclusions:** This pilot study suggests that the addition of the QL to active MP-exposure does affect neural function in humans, altering both resting EEG patterns and the evoked neural response to auditory stimuli, and that there is a tendency for some MP-related changes to the EEG to be attenuated by the QL.

Introduction

Mobile phones (MP) typically operate via a 900-1800 MHz pulsed-signal whose output can be as high as 250 mW. There is concern that exposure to this signal may affect humans, with a resultant body of research testing for MP-related changes in human physiology and pathology. Research has failed to find consistent relations between MP-use and human pathology, however, in terms of neural function there is evidence that MPs have a cumulative effect on neural function (as indexed by the electroencephalogram; EEG), becoming pronounced after fifteen to twenty minutes of exposure (Reiser et al., 1995; Lebedeva et al., 2000; Croft et al., in press). For example, we recently demonstrated that MPs alter both resting EEG and the phase-locked neural response to auditory stimuli as a function of exposure duration, with these changes related to changes in both psychological state and reaction time measures (Croft et al., in press). Although it has not been shown that such changes are detrimental to the user, a number of methods have been developed that purport to attenuate the effect of MPs. The present paper reports on a pilot study designed to test one such device, the Q Link Ally® (QL), in attenuating the effects of an activated MP on human EEG.

The QL is a 'black box' portable EMF-emitting device that emits low-dose (100 mW power uptake) continuous waves at 7,377 MHz (plus a series of upper harmonics; Clarus Products International), and is powered by a 9V D.C. source. It is argued by the developer that this EMF acts as a carrier wave for subatomic 'information', and that this information assists in strengthening an organism's resilience to stressors. However, there are a number of elements to the above theory that are not verifiable (some because critical details have not been made available by the developer, and others because

science does not have the requisite tools at present). This study thus tests an aspect of this thesis that is within the scope of electrophysiology - whether it alters the MP-related effect on neural function (in terms of the EEG). In order to perform this test, neural function while exposed to an active MP was compared to neural function while exposed to both an active MP and QL. The measures employed were resting EEG (the subject sits relaxed with their eyes open), the early phase-locked neural response to a number of tones (the subject selectively responds to one of two tones differing only in frequency), performance (reaction time) and psychological state (how 'activated' the subject is). The null hypothesis being tested is that the QL has no effect on any of the measures (i.e. for each measure, 'MP' = 'QL + MP'). The present study forms part of a larger research project designed to determine the effect of MPs on human EEG, with the 'MP versus Control' comparisons reported elsewhere (Croft et al., in press).

Materials and Methods

Subjects

16 males and 8 females participated in the study and were paid A$10, age ranged from 19 to 48 years (mean = 27.5) and twenty were right-handed. Subjects reported no hearing deficits or neurological history, gave written informed consent and were free to withdraw from the study at any time without penalty. The study was approved by the local ethics committee.

Procedure

On arrival at the laboratory, subjects completed an informed consent form followed by demographics and personality questionnaires. They were fitted with EEG recording

apparatus and seated in a sound attenuated recording booth where an EMF stressor (EMF) and an EMF attenuator (EMF_{att}) were attached. Subjects then performed a 3-minute auditory discrimination task after which the subject sat resting for two minutes with their eyes open (Resting EEG). This five-minute EEG protocol was repeated four times, and this twenty-minute series of tasks was performed three times, each with a different background condition (resulting in a total EEG recording time of sixty minutes). The three background conditions were 'EMF', consisting of exposure to an active MP, 'EMF_{att}', consisting of concurrent exposure to an active MP and QL, and 'CONTROL', consisting of neither MP nor EMF_{att}. Condition order was counterbalanced across subjects, and subjects were unaware of which condition they were engaged in (single-blind). Further to this, immediately before and after each twenty-minute series of tasks, the Thaya Activation-Deactivation Adjective Check List (AD-ACL; Thaya, 1967) was administered. Subjects were continuously monitored throughout the experiment via closed circuit television.

Discrimination Task

Each discrimination task consisted of ninety 70 dB binaural tones, of which half were 1100 Hz [High] and half were 1000 Hz [Low]. Tone duration was 60 ms, with a variable interstimulus interval of 2 +/- 1 s, and stimuli were presented through speakers positioned approximately 1.5 m in front of the subject. Subjects were asked to respond as quickly and accurately as possible to the target tones with a button press. Target-frequency and response-hand were constant within subject and counterbalanced and randomly assigned between subjects. A trial block was given prior to the testing session to familiarise subjects with the task. Behavioural measures obtained were accuracy and

reaction time, and to encourage peak performance throughout the session, after the practice block subjects were offered monetary reward (A$20) to perform at least as accurately and fast during the remainder of the session as they did in the practice block.

Materials

To enhance ecological validity, a standard Nokia 5110 mobile phone was used as a receiver to generate EMF (900 MHz EMF, 217 Hz pulse rate; 0.577 μs pulse width; estimated maximum power 250 mW; actual emissions during experiment not measured). This was positioned 5 cm radial to the subject's scalp midway between Oz and Pz, using a non-metallic external bracket. To reduce variability due to changes in signal strength, a standard script was employed that was sent by a phone in another room. The standard script consisted of spoken extracts from a radio play. These were not audible to the subject, but were played during each condition. The QL was powered by 240 V mains with a 9 V D.C. transformer, and was positioned over the subject's chest (left sternum) using a comfortable chest-strap and operated from a separate room. The position of EMF and EMF_{att} were constant throughout the experiment.

Data Acquisition & Analysis

Behavioural & Psychological measures

Accuracy and reaction time (RT) indices were derived from the discrimination task as the percentage of total targets responded to and the mean time taken to respond to these targets respectively. The first four stimuli from each three-minute task were excluded from the above measures to reduce variability due to confounding effects related to task recommencement. The AD-ACL (Thaya, 1967) consists of 20 words that describe mood

or feelings. Subjects rate the degree to which these adjectives describe their mood at that particular point in time on a four-point Likert-scale. Items relate to the adjectives ‘calm’, ‘excited’, ‘tired’, ‘tense’, and average to form an ‘activation’ scale (low scores represent high activation levels). A difference score was computed from this scale (i.e. ‘condition minus pre-experiment score’) and used as a dependent measure (this will be referred to as ‘Activation’).

Electrophysiological measures

EEG data were collected from 19 scalp sites (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2) using an electrode cap with tin electrodes and referenced to linked ears (AMLABII acquisition system). Electro-oculographic data were recorded using tin electrodes above and below the left eye, and on the outer canthus of each eye. Data were continuously sampled at 512 Hz with a 0.05 to 120 Hz bandpass. Impedances were kept below 5 kOhm. Data were grouped into the following scalp regions: front left (FL) = mean [FP1, F3, F7]; front midline (FM) = Fz; front right (FR) = mean [FP2, F4, F8]; centre left (CL) = mean [C3, T3]; centre midline (CM) = Cz; centre right (CR) = mean [C4, T4]; posterior left (PL) = mean [T5, P3, O1]; posterior midline (PM) = Pz; posterior right (PR) = mean [T6, P4, O2].

Resting EEG: For each 2-minute resting EEG period, the 30-90 second period was EOG-corrected (Semlitsch et al., 1986), divided into 2 s bins, Fast Fourier transformed (10% cosine window) and averaged. Dependent variables were resultant EEG amplitude values grouped into five frequency bands: 1 to 4 Hz (delta); 4 to 8 Hz (theta); 8 to 12 Hz

(alpha); 12 to 30 Hz (beta); 30 to 45 Hz (gamma). These will collectively be referred to as 'FFT'.

Discrimination Task: For each 3-minute discrimination task, data were EOG-corrected (Semlitsch et al., 1986), epoched –1500 to 1000 ms post-stimulus, and the phase-locked component (mean) of these epochs computed for the target and non-target stimuli separately, for each of the frequency bands defined above for FFT data (12 dB/octave roll-off; zero phase shift). Dependent measures for this task were peak percentage power change (relative to the –1000 to –500 ms baseline) in the early sensory phase-locked response (0-200 ms post stimulus) for each of the frequency bands (early sensory change; ESC).

Statistical analyses

Results for the MP versus CONTROL comparison have been reported elsewhere (Croft et al., in press) and will not be addressed here. However, to allow the reader to compare those results to that of the present paper, relevant means and standard deviations are given in Table I, along with a brief description of the MP effect. For each of the FFT, ESC, Activation and RT measures, orthogonal repeated measures polynomial contrasts were employed to test for relations between these indices and condition (QL+MP versus MP), and where appropriate, time (1st versus 2nd half of each twenty-minute condition) and scalp location (sagittal [frontal, central, posterior]; lateral [left, midline, right]). As each condition occurred 1st, 2nd and 3rd an equal number of times, for each dependent variable 'order' was treated as a noise variable and removed by converting scores within

each order (and where appropriate frequency) to z-scores (after being transformed to normality where appropriate). To maintain appropriate alpha levels, for each of the above indices, the number of planned contrasts was restricted to the number of error degrees of freedom (Tabacknick & Fidell, 1989). Only effects due to condition or interactions between condition and topography, time or type will be reported.

To determine whether any QL-related EEG changes were related to subjective state or performance measures, for the QL+MP condition, correlations were performed between the sagittal, lateral and temporal dimensions of any significant contrasts, and both RT and Activation. For example, for a condition * laterality (left versus right) effect, a variable would be computed (mean left minus mean right hemisphere sites) and correlations performed between this new variable and both RT and Activation for the QL+MP condition data. Non-parametric correlations were employed due to difficulties normalising data, and as two tests were performed per significant contrast, α was reduced to 0.025.

To facilitate understanding of the effect of the QL, a summary of the results from Croft et al. (in press) follows. No differences were found between the mobile phone and control condition on reaction time ($p>0.45$) or psychological activation (THAYA; $p=0.08$). In terms of resting EEG, while there was less delta power over right hemisphere sites in the control condition, this differential was accentuated in the MP condition ($p=0.041$), and while there was no affect of MP exposure on alpha at frontal sites, there was an enhancement of alpha over posterior sites in the EMF condition ($p=0.017$). Further, whereas alpha did not change over time in the CONTROL

condition, it increased over time in the MP condition at midline sites (p=0.028). In relation to the phase-locked neural responses, whereas the early sensory theta response decreased over time primarily at midline sites in the CONTROL condition, this decrement was attenuated in the MP condition (p=0.038). Exposure to the active MP also caused a global reduction in the early beta response (p=0.032), with this reduction the result of an enhancement of the natural beta reduction over time that was greatest at frontal and posterior sites (p=0.035). Whereas there was no effect of the active mobile phone exposure at lateral frontal or midline posterior sites, it increased the gamma response at midline frontal and lateral posterior sites (p=0.021).

Results

Behavioural and Psychological Measures

Subjects' mean accuracy levels were 99.3% (SD=1.3) and 99.2% (SD=1.4), and their RTs 383.4 ms (SD=75.4) and 381.5 ms (SD=85.4) for the MP and QL+MP conditions respectively. To approximate normality, reaction time data were transformed according to 't_RT = natural log (RT)'. There were no condition or condition * time effects for RT ($F[1,23]<1.07$; $p>0.313$), and no condition effect for Activation ($F[1,23]=0.64$; 0.432).

Electrophysiological measures

Resting EEG: To approximate normality, data were transformed according to 't_FFT = natural log (FFT)'. Whereas there was a MP-related decrease in delta at right relative to left hemisphere sites, there was a trend-level normalisation of this pattern with the addition of the QL ($F[1,23]=3.37$; $p=0.079$; condition * lateral [left versus right]; Fig. 1a). This normalisation did not relate to Activation or RT changes ($r[24]<0.26$;

p>0.264). The MP-related enhancement of alpha over posterior sites was not altered by the QL (F[1,23]=0.25; p=0.620; condition * sagittal [frontal versus posterior]; Fig. 1b), however, the midline alpha increase over time in the MP condition was affected by the QL, with a trend-level reduction over time (F[1,23]=2.95; p=0.099; condition * lateral [lateral versus midline] * time; Fig. 1c). This reduction was related to increased Activation (trend-level; r[24]=-0.42; p=0.052) but not RT (r[24]=0.05; p=0.824). The addition of the QL increased midline gamma (F[1,23]=4.62; p=0.042; condition * laterality [lateral versus midline]), and this increase was inversely related to Activation (trend-level; r[24]=–0.44,p=0.03) but not to RT (r[24]=0.22; p=0.304). This midline gamma increase was largest at fronto-posterior sites (F[1,23]=5.49; p=0.028; condition * lateral [lateral versus midline] * sagittal [central versus fronto-posterior]; Fig. 2a) and this particular pattern was not related to Activation or RT (r[24]<0.26; p>0.218). Gamma increased as a function of exposure duration across the scalp in QL+MP, whereas the MP condition resulted in a reduction at posterior sites (F[1,23]=4.62; p=0.042; condition * sagittal [frontal versus posterior] * time; Fig. 2b), but this difference did not relate to Activation or RT (r[24]<0.02; p>0.910).

Discrimination Task: To approximate normality, data were transformed according to 't_ESC = natural log (100-ESC)', where more positive t_ESC values represent larger neural responses. The addition of the QL attenuated the left hemisphere decrease and enhanced the right hemisphere decrease in evoked delta over time (relative to the MP condition; F[1,23]=14.09; p<0.001; condition * lateral [left versus right] * time; Fig. 2c). This lateralization pattern was inversely related to RT (trend-level; r[24]=–0.41; p=0.048), but not related to Activation (r[24]=0.16; p=0.445). The MP-related

attenuation of lateral (relative to midline) theta over time was not significantly affected by the addition of the QL ($F[1,23]=1.63$; $p=0.214$; condition * laterality [lateral versus midline] * time; Fig. 1d). The addition of the QL increased left and decreased right hemisphere alpha ($F[1,23]=5.02$; $p=0.035$; condition * lateral [left versus right]; Fig. 2d), but this pattern was not related to RT or Activation ($r[24]<0.32$; $p>0.129$). The global reduction in evoked beta in the MP condition was also present in QL+MP ($F[1,23]=0.01$; $p=0.977$; condition), with an enhanced reduction at midline sites ($F[1,23]=6.17$; $p=0.021$; condition * lateral [lateral versus midline]). While this MP-related reduction in beta occurred as a function of exposure duration, greatest at frontal and posterior sites, there was a trend-level reduction of this temporal change in the QL+MP condition ($F[1,23]=2.07$; $p=0.164$; condition * sagittal [fronto-parietal versus central] * time; Fig. 1e). The addition of the QL caused a marked global decrease in evoked gamma ($F[1,23]=9.58$; $p=0.005$; condition; see Fig. 4) that was greatest at lateral ($F[1,23]=8.39$; $p=0.008$; condition * lateral [midline versus lateral]) and lateral posterior sites. This reduced the MP-related gamma enhancement at frontal midline and lateral posterior sites ($F[1,23]=6.65$; $p=0.017$; condition * lateral [midline versus lateral] * sagittal [front versus posterior]; Fig. 1f). The gamma decrease at left hemisphere sites increased over time ($F[1,23]=4.55$; $p=0.044$; condition * lateral [left versus right] * time). None of the gamma patterns were related to RT or Activation ($r[24]<0.25$; $p>0.240$).

Discussion

The results of this pilot study suggest that the QL impacts on the neural function effects of the MP in terms of both resting EEG and evoked neural responses to auditory stimuli.

With regard to resting EEG, the primary effect was an increase in high frequency activity (gamma) at midline, fronto-posterior sites that was related to a strong enhancement of gamma over the course of the twenty-minute condition (Fig. 2a/b). The addition of the QL also resulted in trend-level attenuation of the MP-related changes to resting delta and the increase in resting alpha over the MP-exposure period, suggesting that the addition of the QL does reduce a portion of the MP effect (Fig. 1a/b). Although the attenuation was trend-level only, the conservative nature of the statistical analyses can be seen in Figure 3 where the control and QL group means are indistinguishable. This suggests that where there were significant differences between the control and MP conditions (Croft et al., in press) but only trend-level differences between the MP and QL+MP conditions, this was due to large variability in the QL+MP condition. There were also alterations to phase-locked neural responses. The addition of the QL caused a right-hemisphere decrease and left-hemisphere increase in the delta attenuation that occurred as a function of exposure duration, a laterality reversal in the alpha band, and a global decrease in the gamma band response. This gamma response was reduced across the scalp, with the reduction largest at frontal midline sites, the result being an attenuation of the MP-related gamma enhancement.

As there is no consensus with regards the meaning of the above resting EEG and neural responses, we are not in a position to fully evaluate the effects. What we may interpret though is how the QL-related effects related to the MP-related effects on neural function, and also how these effects related to the behavioural and psychological indices employed. With regard to the effect of the addition of the QL on the MP-related effects, these were always in the opposite direction to the MP-related effects. That is, the

addition of the QL resulted in function that more closely approximated the control condition, suggesting that it was attenuating the effect of the MP. Such attenuation is consistent with the effect of other EMF devices on stressors. For example, it has been reported that low frequency pulsed electromagnetic fields have protective effects on myocardial infarcts (Albertini et al., 1999; Di Carlo et al., 1999) and hypoxia (Di Carlo et al., 2000), and more closely paralleling the present study, it has been reported that the bioeffects of microwaves are mitigated by the addition of low frequency noise (Litovitz et al., 1997). With regard to the relation between QL-related changes and both psychological activation levels and performance, no unequivocal relations were observed. However, trend-level relations were found. Specifically, the QL-related resting gamma increase was related to decreased activation, the QL-related attenuation of MP-related resting alpha increases related to increased activation, and the QL-related lateralization of evoked delta was related to faster reaction times. As these relations were only trend-level it is difficult to draw too much from them, however, they do suggest that as with the effect of MPs themselves (Croft et al., in press), the addition of the QL resulted in multidimensional effects.

Although it has been demonstrated that the addition of the QL had an effect on neural function (and a trend-level attenuating effect on some of the MP-related changes to neural function), it has not shown which aspect of the QL has caused these effects. That is, although the QL is thought to exert its influence via the interaction of subatomic activity and the biofield, what the study has shown is that the addition of the whole QL mechanism (including D.C. and mains frequency as well as sympathetic resonance technology (SRT^{TM}; Clarus Products International, L.L.C. San Rafael, CA) has an

effect), and so it is possible that the influence was due to the D.C. or 50 Hz power source. Such an interpretation is consistent with the observation that the higher frequencies of neural activity (closer to 50 Hz) were more affected by the addition of the QL (30-45 Hz). An extension of this pilot needs to determine this issue through experimental control (e.g. keeping D.C. and 50 Hz constant in the two conditions and only manipulating the SRT™ aspect of the QL), but at present the results should be interpreted as being due to either the power source *or* the SRT™ technology. However, it should be noted that the QL was not physically close to the electrodes (>30 cm), the distributions of QL effects were not related to the distance between electrodes and the device (but were similar to those typically attributed to neural activity), the magnitude of 50 Hz leakage from the 9 V transformer was too small to account for the QL effect directly, and further, the QL's affect on gamma increased over the course of the exposure. This argues strongly against the thesis that the effects may have been due to direct influence of the QL on the electrodes, and for the thesis that the effects were due to the interaction of neural function with the addition of the QL.

The present pilot study suggests that the addition of the QL to an active MP-exposure does have an affect on neural function in that it altered both resting EEG and the phase-locked neural response to auditory stimuli. Whether the response was beneficial could not be determined from the present study, however, as there were trends to reduced MP-related effects in the QL+MP condition, this suggests that it was attenuating the MP-related effects. Further research is required to substantiate and clarify these findings.

Acknowledgements:

This research was funded by Clarus Products International, LLC, San Rafael, CA, U.S.A.

References

Albertini A, Zucchini P, Noera G. et al. Protective effect of low frequency low energy pulsing electromagnetic fields on acute experimental myocardial infarcts in rats. Bioelectromagnetics 1999;20(6):372-377.

Croft RJ, Chandler JS, Burgess AP, Barry RJ, Williams JD, Clarke AR. Acute Mobile Phone Operation Affects Neural Function in Humans. Clinical Neurophysiology, in press.

Di Carlo AL, Farrell JM, Litovitz TA. Myocardial protection conferred by electromagnetic fields. Circulation 1999:99(6):813-816.

Di Carlo AL, Mullins JM, Litovitz TA. Thresholds for electromagnetic field-induced hypoxia protection: evidence for a primary electric field effect. Bioelectrochem. Bioenerg. 2000;52/1(9-16):16.

Lebedeva NN, Sulimov AV, Sulimova OP, Kotrovskaya TI, Gailus T. Cellular phone electromagnetic field effects on bioelectric activity of human brain. Biomedical Engineering 2000;28(1&2):323-337.

Litovitz TA, Penafiel LM, Farrel JM et al. Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise. Bioelectromagnetics 1997;18(6): 422-30.

Reiser H, Dimpfel W, Schober F. The influence of electromagnetic fields on human brain activity. Eur J Med Res 1995;1:27-32.

Tabacknick BG, Fidell LS. Using Multivariate Statistics (2nd Ed.) New York: Harper Collins, 1989.

Thaya RE. Activation, deactivation adjective checklist: Measurement of activation through self-report. Psychol Rep, 1967;20:663-678.

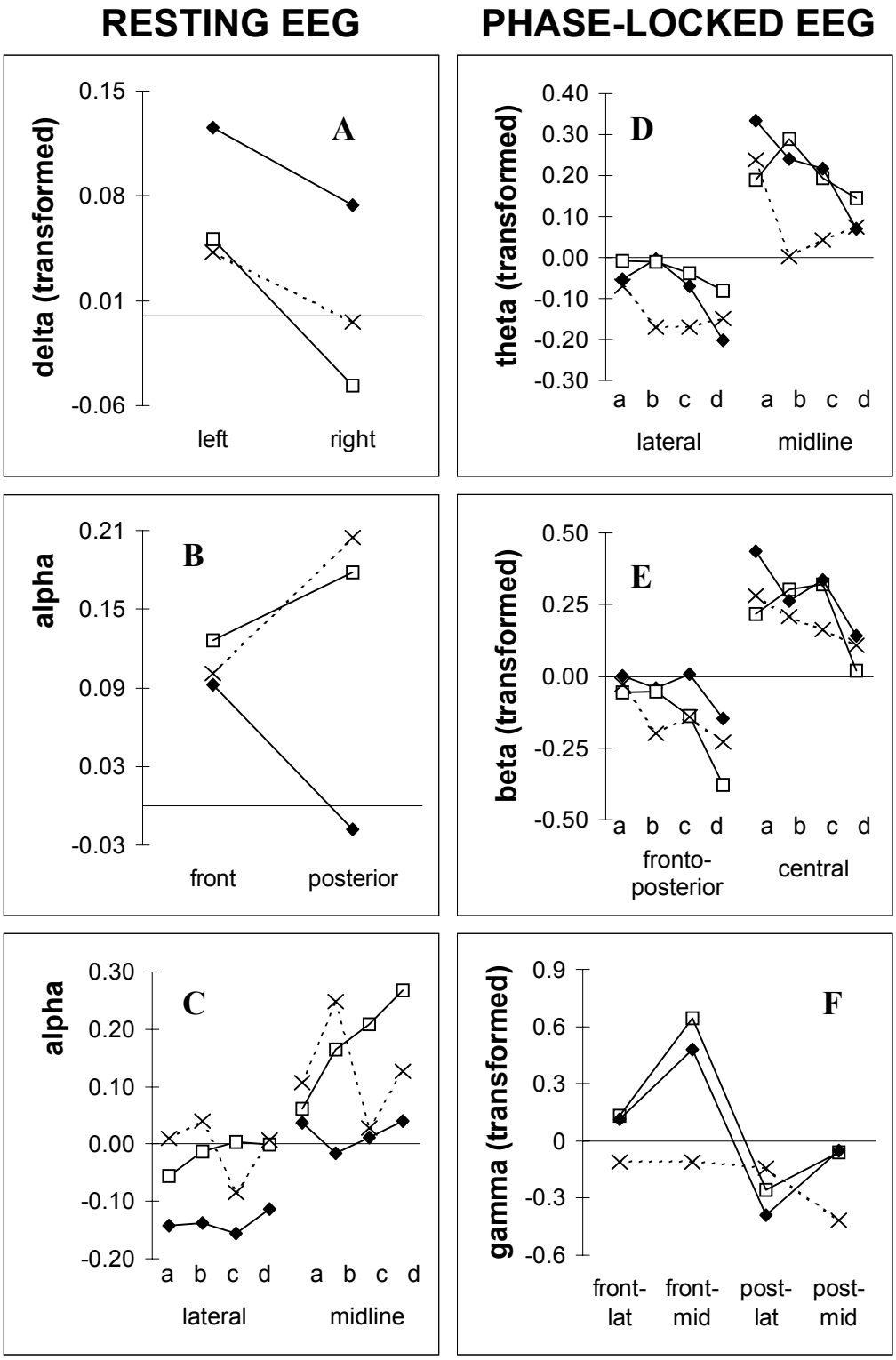
Figure Captions

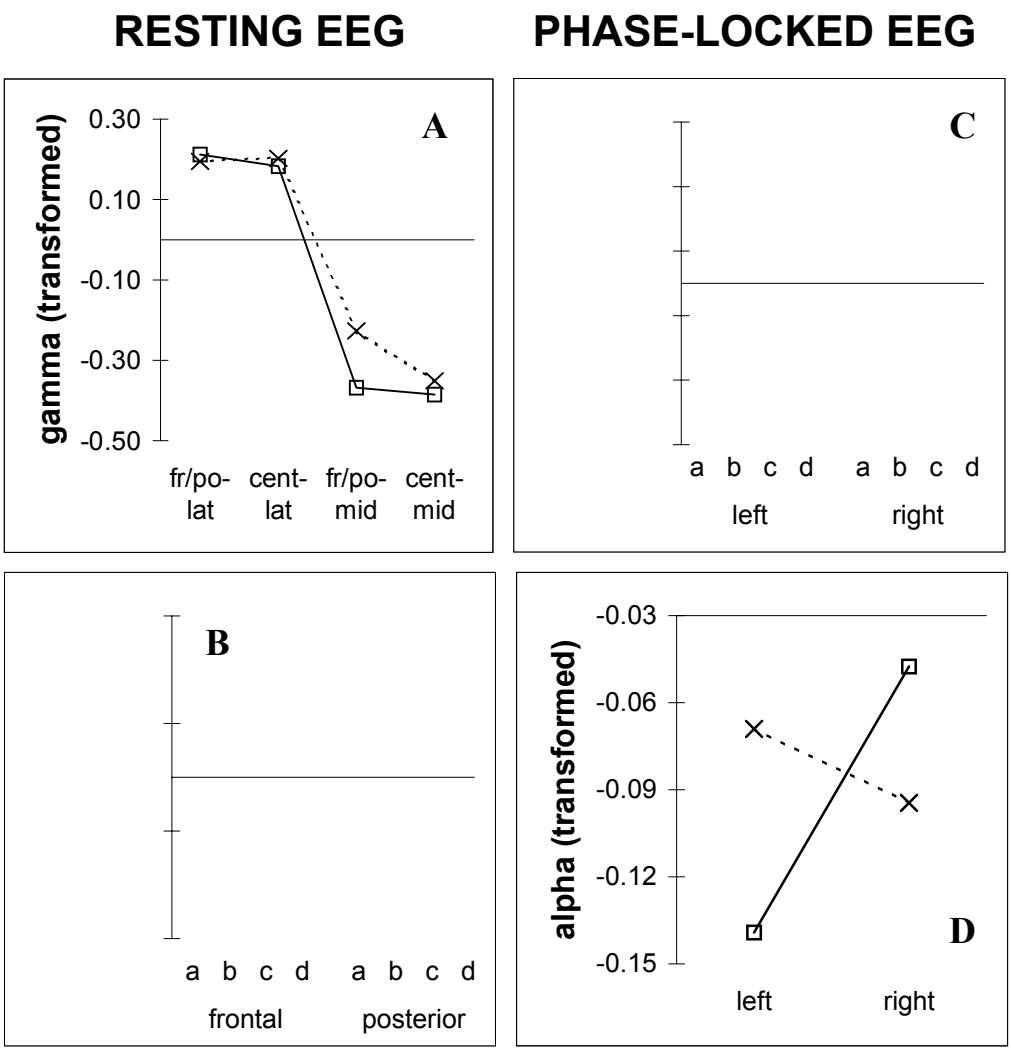
Figure 1. Effects of the addition of QL to *MP-related changes* are shown for grand mean resting EEG (left column) and phase-locked neural activity (right column). Control results are included as a point of reference and are taken from Croft et al. (in press). CONTROL = filled diamonds; MP = open squares; QL+MP = crosses. A. Delta is reduced at right relative to left hemisphere sites in MP, and this differential is remedied with the addition of QL. B. The MP-related increase in posterior alpha was not affected by the addition of QL. C. The MP-related increase in alpha over time at midline sites is inhibited in the QL+MP condition from time 'c' on. D. No significant differences were found between the MP and QL+MP conditions for evoked theta. E. The MP-related decrease in the evoked beta response was reduced by the addition of QL at fronto-posterior sites. F. Evoked gamma decreased in QL+MP, thus removing the MP-related enhancement at posterior lateral sites (post-lat).

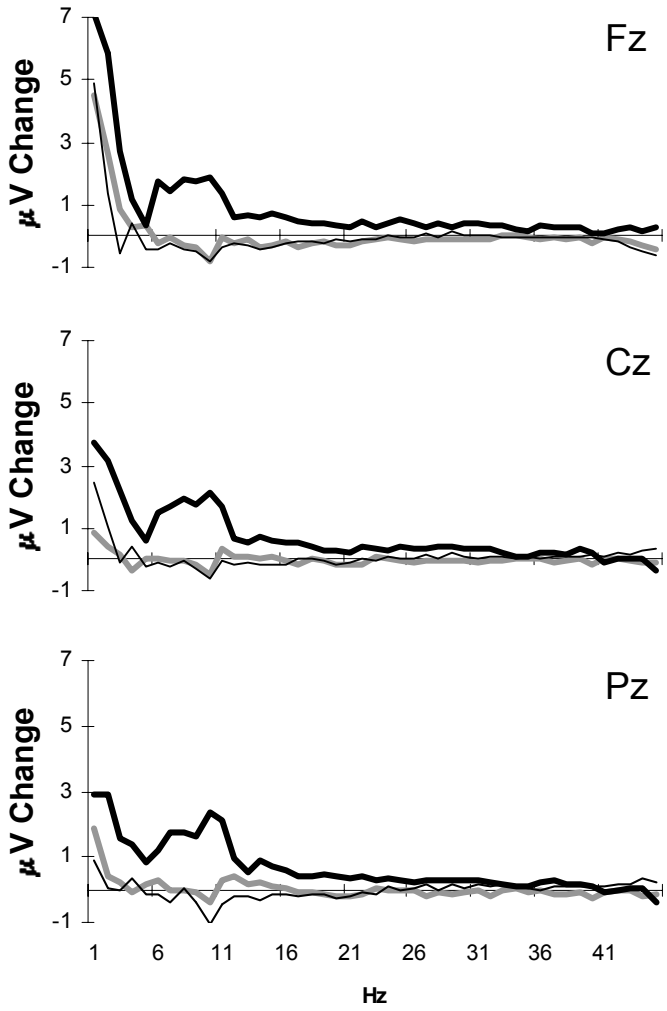
Figure 2. Effects of the addition of QL to the *MP exposure*, on resting EEG (left column) and phase-locked neural activity (right column) are shown (grand mean data). MP = open squares; QL+MP = crosses. A. Gamma was enhanced by the addition of QL at fronto-posterior midline sites (fr/po-mid). B. Whereas gamma decreased over time at posterior sites in the MP condition, it increased when the QL was added. C. The change in phase-locked delta over time (decrease at left and relative stability at right hemisphere sites) was reversed by the addition of QL. D. Alpha was enhanced over left and reduced over right hemisphere sites by the addition of QL.

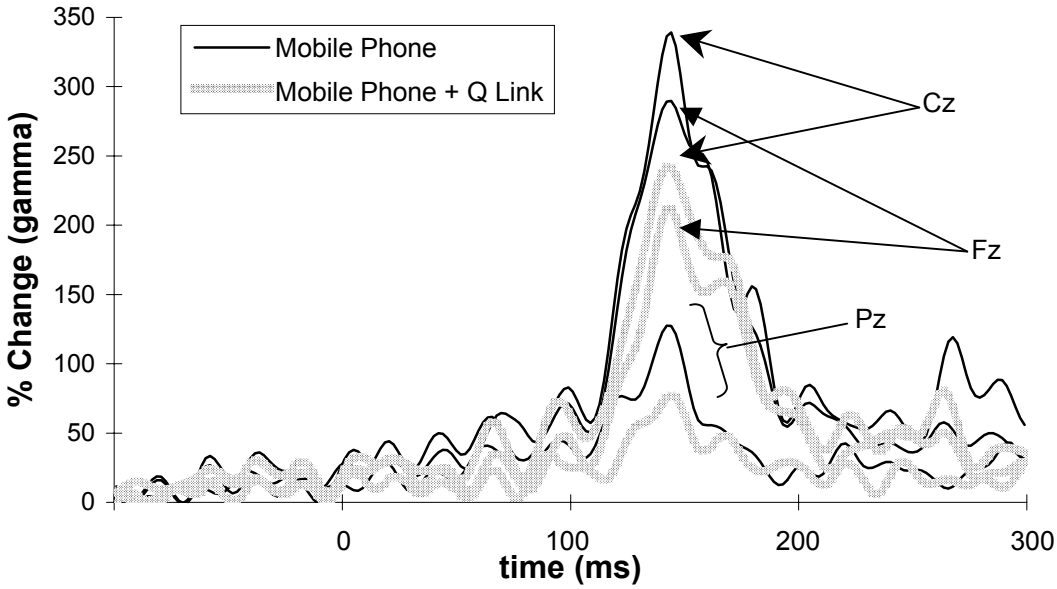
Figure 3. The grand-mean change over time in resting EEG (2nd minus 1st half of the condition) is shown for the control (thick grey lines), MP (thick black lines) and QL+MP (thin black lines) conditions separately. Of particular interest is that the MP exposure caused a marked increase in alpha (8-12 Hz) that is not present in QL+MP.

Figure 4. The grand-mean phase-locked gamma responses are shown as a percentage of baseline at Fz, Cz and Pz, for the MP and QL+MP conditions separately.


RESTING EEG
PHASE-LOCKED EEG
A
delta (transformed)
0.15
0.08
0.01
-0.06
left
right
D
theta (transformed)
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
a b c d a b c d
lateral
midline
B
alpha
0.21
0.15
0.09
0.03
-0.03
front
posterior
E
beta (transformed)
0.50
0.25
0.00
-0.25
-0.50
a b c d a b c d
fronto-
posterior
central
C
alpha
0.30
0.20
0.10
0.00
-0.10
-0.20
a b c d a b c d
lateral
midline
F
gamma (transformed)
0.9
0.6
0.3
0
-0.3
-0.6
front-
lat
front-
mid
post-
lat
post-
mid


RESTING EEG
PHASE-LOCKED EEG
A
gamma (transformed)
0.30
0.10
-0.10
-0.30
-0.50
fr/po-lat
cent-lat
fr/po-mid
cent-mid
C
a b c d a b c d
left
right
B
a b c d a b c d
frontal
posterior
D
alpha (transformed)
-0.03
-0.06
-0.09
-0.12
-0.15
left
right


Fz
Cz
Pz
μV Change
7
5
3
1
-1
1
6
11
16
21
26
31
36
41
Hz


350
300
250
200
150
100
50
0
% Change (gamma)
Mobile Phone
Mobile Phone + Q Link
Cz
Fz
Pz
0
100
200
300
time (ms)