



Neural mechanisms of perceptual grouping in humans as revealed by high density event related potentials

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Received 8 October 2001; received in revised form 15 November 2001; accepted 17 November 2001

Abstract

Behavioral studies suggest that perceptual grouping by proximity occurs earlier than grouping by similarity. This notion is supported by recent electrophysiological evidence that proximity grouping generates earlier occipital activation relative to grouping by shape similarity. The current work further investigated neural substrates that differentiate grouping by proximity and grouping by colour similarity by recording high density event related potentials. Subjects discriminated perceptual groups defined by either proximity or colour similarity. Proximity grouping resulted in short-latency modulations of medial occipital activity followed by longer latency modulations in the occipito-parietal cortex. Grouping by colour similarity, however, produced only long-latency occipito-temporal modulations. The results support the proposal that grouping by proximity and grouping by similarity have neural substrates over distinct time courses and cortical areas. © 2002 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Colour; Cortex; Event related potentials; Grouping; Proximity; Similarity

Pq oqfl nx s fi fluzs qrq fi t q r zo u f i z fir t q t y nz flq oqfl mx qy fi fi s nzu q pu o q q qz u uq uz t q u nx qxp uz fi ot zw fi flq oqfl mx finvqo rfi t ust q -fi pq fl fioq uzs. Gq mx fl ot fixfis u upqz u qp xm t m s upqs fi fluzs fir finvqo ofiz u qz uz fi flq oqfl mx t fixq g7i. Ffi q ny flxq, t q fl u zouflxq fir fl fi uy u mq t m flmu nxx ofi q finvqo qzp fi nq s fi flqp fisq t q.] t q fl u zouflxq fir uy wmu oxny t m qxqy qz ut uy wmu rqm q uz t q qxp qzp fi nq s fi flqp fisq t q. G fi fluzs fl fioq q t m q nqqz m y qp fi mwq flxnoq m nz qmx nq uz t q u nx fl fioq uzs qny g2,6i.

Ozq fir t q uy flfi nz u q qsmpuzs flq oqfl mx s fi fl uzs u t qt q fi zfi t q ny qzq mx n mq zpq fluz t q s fi fluzs fl fioq q nmqp fiz purq qz Gq mx xm . Bqt m ufi mx q qmot gl,3,4i rfi zp t m nvqo q flfizpqp rm q fi t q pu o uy uzmufiz fir flq oqfl mx s fi fl pq zqp n fl fi uy u t nz n uy wmu fir t mflq, ssq uzs t m fl fi uy u s fi fluzs mwq flxnoq qmxq nzp/fi rm q t nz s fi fluzs n uy wmu . A qoqz p q mx mqp s fi fluzs qxmqp zq mx n mq n qof i puzs q qz qxmqp n mw flfi qz unx

(EWP) fi pu o uy uzmufiz fir flq oqfl mx s fi fl pq zqp n fl fi uy u fi t mflq uy wmu g5i. I m rfi zp t m fl fi uy u s fi fluzs uzp oqp mflfi uu q no u u nq qqz 100 nzp 120 y m q uy x fiz q fi q t qy qpunxfioouflunxofi q .] t u qmx flfi uu u m rfixfi qp n nz fioouflu fi -flmuq mx zqs mu u ut nz fiz q fir 180 y nzp xmsq ny flxu pq fi q t q ust t nz t q xqr t qy u flt q q. Hfi q q , s fi fluzs n t mflq uy wmu m q qo qp fizx uz mfixz -xmqzo fioouflu fi -qy flfi mx zqs mu u ut nz fiz q fir 260 y nzp xmsq ny flxu pq fi q t q xqr t nz ust t qy u flt q q .] t q EWP q x ssq t m t q s fi fluzs fl fioq q pq zqp n purq qz Gq mx xm y m t m q pu uzo zq mx n mq .

Bqt m ufi mx q qmot t m t fi z t m uy wmu fir ofixfi u mflfi q r x fl u zouflxq fi s upq s fi fluzs g10i.] t q o qz fi w ofiy flmfp EWP ofi qxmq fi s fi fluzs n fl fi uy u ut t fi q fi s fi fluzs n ofixfi uy wmu fi q ny uq t q t q t q q s fi fluzs fl fioq q t m q uy wmu zq mx n mq . c q qof i pqp t ust pqz u EWP r fiz t y nz nvqo t fi pu o uy uzmqp pu flxu uz t uot xionkxqy qz q q qut q q qzx flnoqp, s fi flqp nmqp fiz fl fi uy u , fi s fi flqp nmqp ofixfi uy wmu . Durq qzoq m q q q fin mwq n n no uzs EWP fi t q zurfi y uy xur fiz EWP fi t q s fi fluzs uy xu fi qx oipmq n mq fir t q

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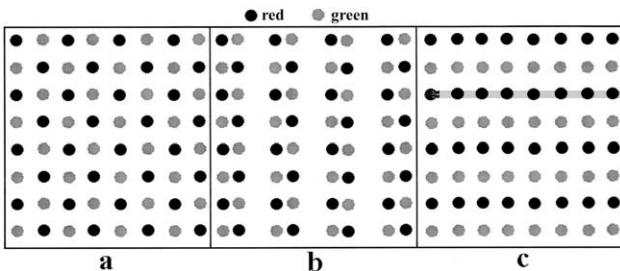


Fig. 1. Illustrations of the stimuli used in the present study. (a) The uniform stimulus; (b), the proximity-grouping stimulus in which local elements group into columns; (c), the similarity-grouping stimulus in which local elements group into rows.

s fi flus s fl fioq q . b fixnsq fiftis nftt uq fir EWP q q omx xmqp fi q uy mq t q sqzq mfi fir s fi flus qxmqp purq qzoq m q .

EWP q q qof pqp r fiy 16 t qnxt fix z qq (12 y qz, rfi fuy qz; nsqp 20 26 qm). Axx nvqo q q us t t nzpqp, t np zfi y mx fi ofi qo qp- fi-zfi y mx uufiz nzp qflfi qzfi ofixfi nxuzpzq .] t q uy xu ofiz u qp fir m - mq xm waq fir qxqy qz (qp fi s qqz pu w) uq nz 8 × 8

m m (Fus. 1).] t q zurfi y uy x ofiz u qp fir nxq zmq qp nzp s qqz pu w pu un qp q qzx no fi t q xm waq .] t q fl fi uy u -s fi flus uy xu ofiz u qp fir nxq zmq qp nzp s qqz pu w m nzsqp uq m m fi rfi y fi fi ofix y z n npv uzs t q pu nzoq nq qqz fi npvnoqz fi fi ofix y z fi t m t q pu nzoq nq qqz fi zqm fi qy fi q fi (fi ofix y z) q q 0.14 nzp 1.1°, q flqo u qx .] t q uy uxmu -s fi flus uy x m y npq n y fi uzs t q qp nzp s qqz pu w uq t q zurfi y uy x fi rfi y fi fi ofix y z ut qxqy qz fir npqz wonx ofixfi . Enot xfionx t nflq nzp sxfimnx uy x m m n qzpqp nz nzsq fir 0.47° × 0.47° nzp 7.8° × 7.8°, q flqo u qx .] t q t fi u fiz nx fi q wonx pu nzoq nq qqz fi npvnoqz xfionx t nflq m 0.57° rfi t q zurfi y nzp uy uxmu -s fi flus uy xu A tuq mufiz o fi fir 0.3° × 0.2° m ofiz uq fi x u uxq uq t q oqz q fir mnxwnnws fi zp t wt t np mx y uenzoq fir 0.02 op/y² .] t q uy x flm q z t np mx y uenzoq fir 0.88 op/y² .] t q qp nzp s qqz pu w t np Cfuy y u ufiz Iz q - zmufizmxq pq L'Eoxmuaq (CIE) ofifi puemq fir 0.541/0.320 nzp 0.289/0.603, q flqo u qx .] t q uy x p mufiz m 200 y .] t q uq q uy x uq mx muqp nzpfy x nq qqz 800 nzp 1200 y . [nvqo pu o uy uzmqp ofix y z q fi

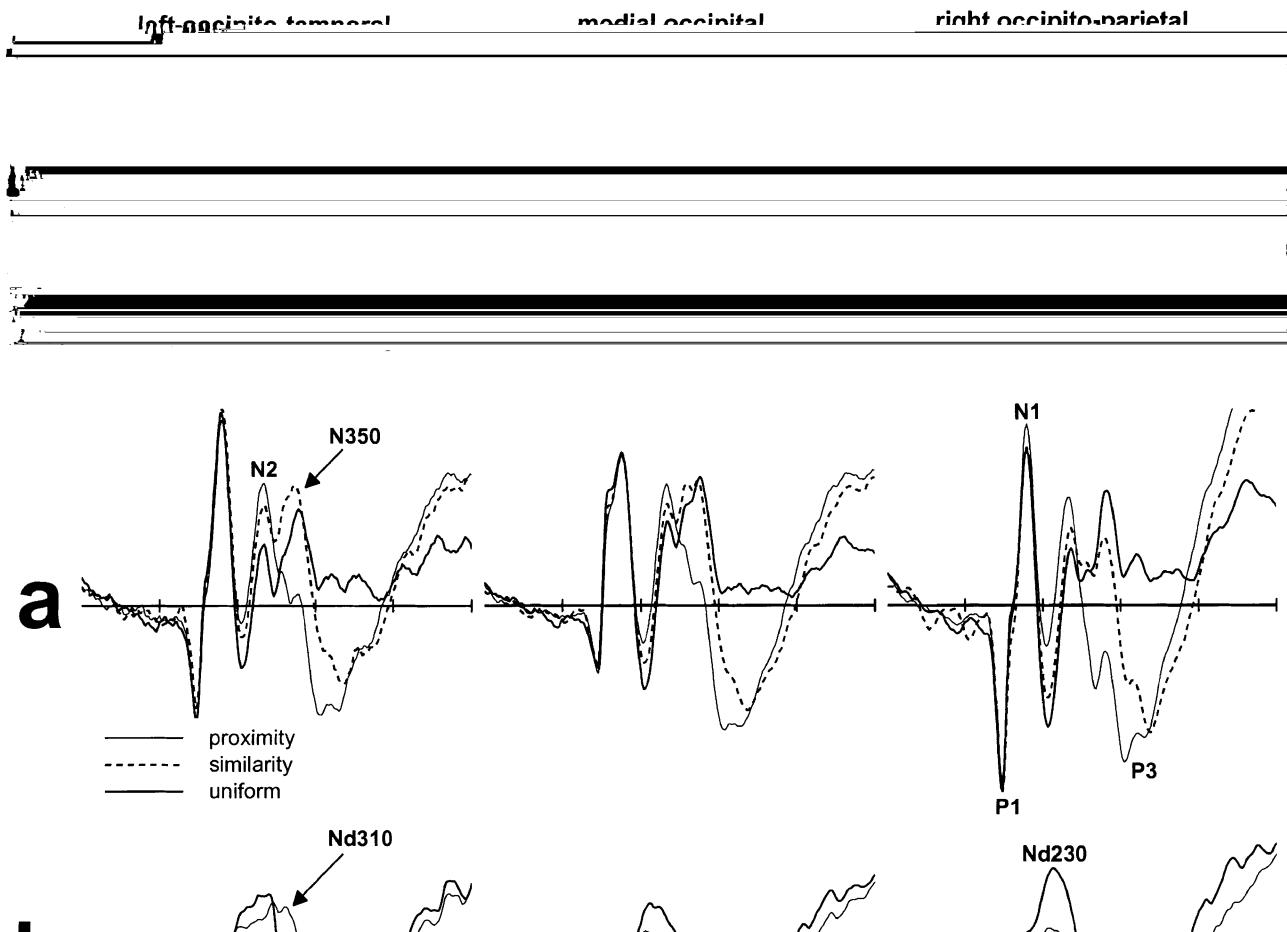


Fig. 2. The effect of grouping by proximity and by colour similarity. (a) Grand averaged ERPs elicited by the uniform and grouping stimuli at three electrodes over different brain areas; (b), difference waves related to proximity and similarity grouping.

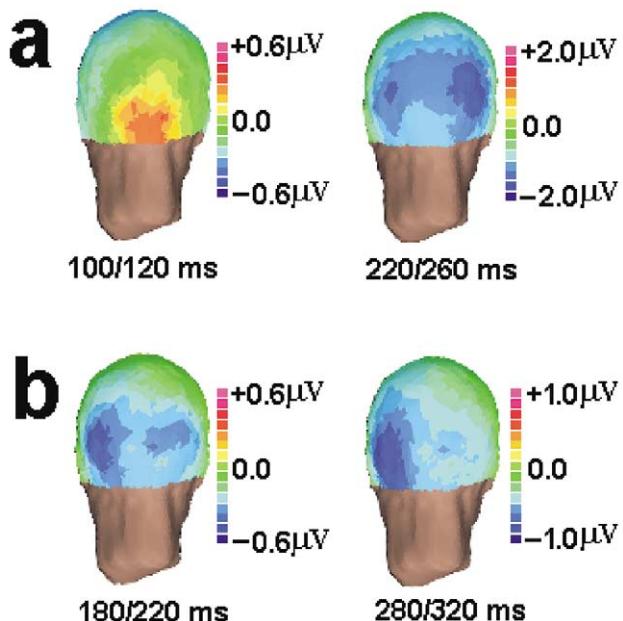


Fig. 3. Scalp voltage maps of difference waves related to: (a), grouping by proximity: the Pd110 focused over the medial occipital cortex and the Nd230 focused over the right occipito-parietal areas; and (b), grouping by similarity of colour: the Nd310 focused over the left occipito-temporal areas.

fi s nzu mufiz fir t q s fi flus pu flm n fl q uzs fizq fir t q fi n fiz. Ar q 100 fl no wq ux, nvqo q q fl q qz qp ut 1000 ux qz nxio.] t q zurfi y, fl fi u y u -s fi flus, nzp uy umu -s fi flus uy xu q q fl q qz qp nzpfy x fiz 32, 34 nzp 34% fir t q ux, q flqo u qx.] t q qxqo fioqfliit nxis ny m qof pqp m u fi fl q ufi fi w ḡi.] t q EWP u qnot uy x ofizpuufiz q q m q ns q p qflmmqx fir-xzq, ut m q ns uzs qflfot nqs uzzus 200 y nqrfi q uy x fiz q nzp ofiz uzs rfi 1000 y.] ux ofiz ny uzmq p n q q nxe w fi y oxq flfi qz ux q oqqpus ±75 μb m nz qxqo fipq fi q flfiz q q fi q q ox pqp r fiz t q m q ns q.] t q nmqkxq rfi EWP y qm q m t q y qn fixnsq fir t q 200-y fl q uy x ux q nx] t q y qn fixnsq fir EWP nzp purq qzoq m q q q fin nuzq p m 20-y ux q nx m uzs m 60 y nzp ofiz uzs z u 500 y flfi - uy x m fioouflunx flmuq nx nzp qy flfi nx qxqo fipq.] t q y qn flqmw ny flux pq fir purq qzoq m q q nvqo qp fi nznx q fir munzoq ut G fi flus (fl fi uy u fi uy umu q zurfi y uy xu) nzp Hqy u flt q q (qxqo fipq fiz t q xq q us t t q y u flt q q) m uzp qflqzpz m u m q fl fi q t q fioouflunx qy flfi nx nzp flmuq nx qxqo fipq.] fi p q q y u q t q q rro u u mofiz q mu q m, fizx t q y m q F nx q t m t fi q p u zu onz qrrqo m qflfi qp.

Wqno uifz uy q (W) q q rm q fi fl fi uy u - t nz uy u xmu -s fi flus uy xu (514 q 534 y; t = 4.736, P < 0.001), ofiz u qz ut fl q ufi qflfi gl, 3i.] t q q m zfi u zu onz purq qzoq u q fi m q nq qqz t q fi ofizpuufiz (4.6 q 4.3%; t = 0.708, P > 0.5).

G nzp m q ns q p EWP nzp s fi flus qxqo p urq qzoq m q mq t fi z u Fis. 2. P fi uy u s fi flus m u p q q p n mflfi uu q m q t m flqmwq n q qz 100 nzp 120 y fi q t q y qpnx fioouflunx ofi q (Pp110) u p w m q p n t q y m u q rro fir s fi flus ($F_{(1,15)} = 4.82$, $P < 0.04$).] t q flfi uu u m rfixfi q p n nz fioouflu flmuq nx zqs m u u nq qqz 180 nzp 260 y (Np230; $F_{(1,15)} = 4.62$, $P < 0.04$), t wt t np m xmsq ny flux pq fi q t q us t t nz t q xq t q y u flt q q ssq q p n m us zu onz u q mofiz fir G fi flus \times Hqy u flt q q ($F_{(1,15)} = 4.57$, $P < 0.05$). [onxfl fiffis mft q q q p m z fiz m nvqo t qnp y fipq x fi u m u q t q rfi oufir t q qrrqo fir fl fi uy u nzp u y u m u s fi flus (Fis. 3). Axt fi st t q uy umu -s fi flus qxqo p urq qzoq m q t fi qp m y mxx flfi uu u fi q t q y qpnx fioouflunx ofi q, t u qrrqo m zfi u zu onz.] t q qrrqo fir s fi flus n ofixi uy umu m fizx q qo qp u mn fimp zqs mu u nq qqz 180 nzp 380 y fi q t q fioouflu flfi mx qsfiz (Np310) u p w m q p n t q y m u q rro fir G fi flus ($F_{(1,15)} = 4.49$, $P < 0.05$).] t q xmq flt mq fir t q Np310 (260 380 y) t fi qp m xmsq ny flux pq fi q t q xq t q us t t q y u flt q q m u p w m q p n m us zu onz u q mofiz fir G fi flus \times Hqy u flt q q ($F_{(1,15)} = 4.58$, $P < 0.05$).

Axt fi st t q xfionx qpxy qz q q pq zqp n purq qz ofixi u t q o qz p, fl fi uy u s fi flus u p o q p u y u m q p n t q y qpnx fioouflunx y fip xmuqz m 110 y m u fi fl q ufi fi w ḡi, ssq uzs t m fl fi uy u s fi flus xmsqz p qflqz p fiz qfl q qz mufiz fir m flmuq qxmuqz t ufl nq qqz xfionxqpxy qz nzp u u p qflqz p qz fir u nxrqm q (ot m t nflu nzp ofixi) t m pq zq xfionx uqy. I u zmuqz t m t q Pp110 q qo m q flfiz q fir fi uqz mufiz pu o u u mufiz t m flm w xmuqz s nq p u t q s fi flus uy xmuq q t q qmuq EWP ofiy flfizqz qpmq p fi u m p u o u u mufiz u m q t m flqmw m mfi 165 y (N1) gl2i. Iz npwpuufiz, t q Pp110 m q u p qz rfi t q fl fi u y u -s fi flus ofizpuufiz n zfi rfi t q uy umu -s fi flus ofizpuufiz pq fluq t q rm t m u m p u o u u mufiz m q u q p zp q nfi t ofizpuufiz.] t q Pp110 ofi finfi mq q u p qz o r fiz fi t q puq ḡ, 11i u qz rfi ouzs t m t q umq fi fl q umq ofi q u u fix q p u qmx fl q ofl m fl fioq uzs ot m s q-s fi zp q s qmuq n zp s fi flus.] t q Pp110 y m q qo xfionx ou o u no u u u t q qmx u nxmqm. Axq zmu qx, q-qz nz rqqpnno wr fiz t u t q u nxmqm y m u p o q fiz q flfiz q fi t q s fi flus uy xu u t q qmx u nxmqm nzp fl fip oq t q Pp110.] t q q zq p fi nq pu uzs u t q p u r t q puq.] t q Np310 q xmuq p n uy u m u s fi flus flqmwq p q qz xmuq t nz t q xmuq ofiy flfizqz (Np230) q xmuq p fi fl fi uy u s fi flus.] t q fiz q p q xmuq fir uy u m u -s fi flus purq qzoq m q fl fi u p q m zq fift u fixfis w m mu rfi t q xfi q nq t m ufi m q flfiz q fi uy u m u -t nz fl fi uy u -uy xu Nfi q t m nvqo t np fi qxqo t q s fi flus uy xu nzp t qz pu o u u m q ofix y z q fi fir t q pu flm.] t , t q xmuqz purq qzoq nq qqz t q Np310 nzp t q Np230 y m q qo t q p q xmuq fir uy u m u -s fi flus fl fioq uzs m t q n s q fir qxqo uifz, pu o u u mufiz, fi fi t q flfi -

flq oqfl mxnznx u .] fiftis nftt q fir t q q zqs mu uq wru
omq t m t q fioouflu fi-flmqq mxmqm mq qzs ns qp uz fl fi uy u
s fi fluzs t q qm t q fioouflu fi- qy flfi mx mqm mq uz fix qp
uz uy wmu s fi fluzs, ssq uss t m pu uzo n mz mqm
mq uz fix qp uz purq qz s fi fluzs fistlq mufiz . Durq qz
t qy u flt q u xmq muu mufiz uz fl fi uy u mz p uy wmu
s fi fluzs y m q x r fiy t q pfiy uenzoq fir t q fi t qy u
flt q q uz xfi q t us t flmzx r q- qzo mzmx u (qq
Wqr. ggi rfi y fi q pu o uzfiz).

] t q qrrqo fir s fi fluzs n t nftlq uy wmu m mx fi ot m-
no q u qp n nz fioouflu fi- qy flfi mx zqs mu u ut m xq
t qy u flt q q pfiy uenzoq ggi.] t q uy wmu y fi flt fixfis , omxfi
pu un uufiz, mz p t qy u flt q q pfiy uenzoq fir t q purq qzoq
mq uz t q fi puq ssq t m s fi fluzs nmqp fiz
t nftlq fi ofixfi y m nq y qpmqp n m uy wmu y qot nzu y
fi q t q fioouflu fi- qy flfi mx ofi q . Hfi q q , u u flfi unq
t m, qxmnu q fi t nftlq, ofixfi u m y fi q muqz finvqo
rqm q, mz p t sqzq mqp qmxaq fiz q fir s fi fluzs fistlq m