

; OLQN FRORU EOLQG D V\ VWHPDWLF UHYLHZ
GHILFLHQF\ FRJQLWLYHO\ DQG QHXURORJLFD

=H\&DL

8QLYHUVLW\ RI 7RURQWR 0LVVLVVDXJD 8QLYHUVLW\ RI 7RURQWR 0LVVLVVDXJD

\$EVWUDFWRU YLVLRQ GHILFLHQF\ &9' FDQ DIIHFV SHRSOH\ V SHUFHSWL
RUGHU WR GLVWLQJXLVK FRORUV GLIIHUHQW FRQHV GLIIHU LQ VSHFWUL
231 /: 231 0: \$7) &1*\$ &1*% *1\$7 3'(+ DQG 3'(& DUH UHVSQRVLEO
YLVLQR GHILFLHQF\ 0XWDWLRQ LQ WKHVH JHQHV FDQ FDXVH GHILFLHQF
FRORU YLVLRQ VHQVLWLYLW\ *HQH WKHUDS\ WKDW WDUJHW WKHVH JHQH
YLVLQR \HW VXFK PHWKRGV UHPDLQ LQ GHYHORSPHQW DQG QRW ZLGHQ\
JDPXW GLIIHUHQFH LQ FRORU YLVLRQ GHILFLHQF\ LQGLYLGXDOV DQG SU
\$FFRUGLQJ WR UHGXFWRQ WKHRU\ WKH &9' SDWLHQW ZRXOG EH ELDVH
JDPXW &RPSHQVDWLRQ JODVVHV VKRZHG LPSURYHG SHUIRUPDQFH LQ \,
PHWKRG ZDV QRW XVHG IXUWKHUPRUH LW LV HIIHFWLYHQHV RQ RWKHU
WKH HIIHFWLYH UHFYHU\ RI JHQH WKHUDS\ DQG FRPSHQVDWLRQ JODV
UHFRPPHQGHG IRU EHWWHU UHFYHU\ LQ &9' SDWLHQWV

,QWURGXFWLRQ

&RORU YLVLRQ GHILFLHQF\ &9'
ZKHUH WKH SDWLHQW\ V FRORU
UHGXFHG RU FRPSOHWHO\ LPSDL
QRW RQO\ LPSDLUH LQ GDLO\ O
DOVR UHVWULFWHG LQ SXUVXLQ
IDVKLRQ GHVLJQ DQG ILUHILJKW
LV DFKLHYHG WKURXJK OLJKW VM
FRQH FHOOV WKH 6 FRQHV VKR
FRQHV PHGLXP ZDYHOHQJWK OI
ZDYH OHQJWK > @ (DFK FRQH
ZDYHOHQJWK LQ WKH OLJKW VSH
GDPDJH LQ RQH RU PRUH WKHVH F
WR UHFHLYH PLVVLQJ IDOVH VLJQ
7KH KXPdq H\H FRQVLVWV RI
FRYHU WKH UHWLQD VXUIDFH RIV
IRU YLVXDO VHQVDWLRQ > @
WUDQVPHPEUDQH RSVLQ ZKLF
ELQGV WR WKH OLJKW VHQVLWLY
> @ :KHQ D SKRWRQ LV DEVR
FKURPRSKRUH IURP FLV IRUP \
WUDQVPHPEUDQH RSVLQ LV DF\
SKRWRWUDQVGXFWLRQ FDFVDFGH
SKRWRQ LV DEVRUEHG LV EDVHG
GXH WR WKH GLIIHUHQFH LQ NH\
WKH FKURPRSKRUH > @ 7KHVH
DFWLYDWLRQ HQHUJ\ DQG VKLIW\
&XUH IRU &9' IRFXVHV RQ QHXUR
FRJQLWLYH SHUVSHFWLYH +RZ
FRORU YLVLRQ GHILFLHQF\ DU
GHYHORSPHQW > @ 7KLV VW;

QHXURORJLFD DQG FRJQLWLYH DVS
UHVSHFWLYH WUHDWPHQWV WR FXUH &

&RQJHQLWDO FRORU YLVLRQ GH

&RQJHQLWDO FRORU YLVLRQ GHILFLHQ
FKURPRVRPDO GHILFLHQF\ WKDW DIIHF
ZKLFK UHVXOWV IURP DEQRUPDOLWLHV
RU DOO WKUHH FRQH W\SH SKRWR
0DOIXQFWLRQLQJ RI FRQHV LV HLW
SKRWRWUDQVGXFWLRQ FDFVDFGH RU W
RI WKH F\FOLF JXDQRVLQFH PRQRSKR
FKDQQHO > @ 7KH VXFODVV RI &&9'
RQ WKH VHYHULW\ DQG ZKDW W\SH RI
DQRPDORXV WULFKURPDF\ DQG GLF
GDPDJH LQ RQH FRQH W\SH PRQRFK
GDPDJH LQ WZR RU PRUH FRQH W\SHV >
\$QRPDORXV WULFKURPDF\ LV WKH PRV
FRORU YLVLRQ GHILFLHQF\ DQG LV GHIL
W\SH EHLQJ QRW FRUHFWO\ DOLJQ
DQRPDORXV WULFKURPDF\ PD\ QRW K
YLVLQR DQG DPSOLILFDWLRQ RI WKH U
DOORZ DQRPDORXV WULFKURPDF\
UHODWLYHO\ QRUPDOLJHG FRORU YLV
DQRPDORXV WULFKURPDF\ GLFKURPDF
RQH FRQH W\SH DQG SDWLHQWV ZLWK
WR VHH FRORU ZLWKLW WKLV FR
ORQRFKURPDF\ LQYROYHV KDYLQJ RQ
FRQHV DW OHDGLQJ WR DFRPSOHWH O
> @ 7DEOH VKRZV WKH YDULRXV IRUP
V\PSWRP

Table 1. GLIIHUHQFH LQ DIIHFWHG F
DPRQJ GLIIHUHQW W\SHV RI FRU

'HILFLHQF	&RQHVDII	V\PSWRP
Anomalous trichromacy		5HGXFHG VHWKHF FRUUHVSRQ FRQH ZDYH
SURWDQR	/	5HGXFHG VHWKHF WRORQJZDUHG
GHXWHUDQ	0	5HGXFHG VHWKHF WRPHGLXP OHQJWKJ
,QFRPSOHWH	6	5HGXFHG VHWKHF WRVKRUWZ EOXH
GLFKURPD		,QDELOLW\W RIWKHPLVW W\SH
3URWDQR	/	&DQQRWVH ZDYHOHQJV
'HXWHUDQ	0	&DQQRWVH ZDYHOHQJV
WULWDQR	6	&DQQRWVH ZDYHOHQJV
PRQRFKURF / FRQH	0 6	,QDELOLW\W FRORU
0 FRQH PRQRFKURF	/ 6	
6 FRQHPRQR	0 /	
5RGPRQRFKU LQFRPSOH DFKURPDW	/ 0 6	

; OLQNDJH

\$V DFFRUGLQJ WR ; OLQNDJH PE
GLVHVV DUH OHVV VHYHUH LQ II
WKH GLIIHUHQFH LQ KRZ PDOHV D
; FKURPRVRPHV > @ 6LQFH ;< PD
FKURPRVRPH JHQHWLF PXDWL
DIIHFV WKH RQO\ FRS\ RI WKDW J
WZR FRSLHV RI ; FKURPRVRPH WI
OLNHO\ WR EH DIIHFWHG E\ ; OL
VLQFH WKH XQDIIHFWHG [FKU
VXIIILFLHQW DPRXQW RI XQDIIHF
HVVHQWLDQ PHWDEROLF IXQFWI
GLVHVV &&'9 LV FRQVLVWHQW
WKDQ IHPDOHV > @ &&' LV N
PDOHV DQG RI IHPDOHV > @
+DZDVVD XQLYHUVLW\ VKRZV WK
IHPDOHV DUH DIIHFWHG ZLWK &
WHVWLQJ RI &&' DPRQJ %ODFN
FKLOGUHQ LQ 'XUEDQ DOVR VKRZ
) > @

1HXURORJLFDQ LPSDFW

'LIIHUHQW FRQHV DUH DVVRFLDV
WKH ; FKURPRVRPH 6 FRQHV EC
ORFDWHG RQ DXWRVRPDO FKURF
UHG SLJPHQWV DUH ORFDWHG
FKURPRVRPH ;T DV WKH ORQJ

JHQH 231 /: 0 FRQHV JUHHQ SLJPHQW
YDULHG LQ QXPEHU DPRQJ FRORU YLV
LQGLYLGXDOV EXW DOLJQ KHDG WR W
DV WKH PHGLXP ZDYH VHQVLWLYH RSVL
> @ 'LIIHUHQW FRQHV KDYH GLIIHU
VHQVLWLYLW\ WRZDUG GLIIHUHQW OLJ
RUGHU WR GLVWLQJXLVK FRORU FRQW
FRQHV WKDW GLIIHUV LQ VSHFWUDO VH
&RORU GLVFULPLQDWLRQ LV SURFHVVH
VXE\WHPV > @ :KHQ GLVFULPLQDWL
ILUVV VXE\WHP FRPSDUHV WKH 6 FR
FRQHV DQG WKH VHFRRG V\WHP FRPS
IRU FRORU GLVFULPLQDWLRQ RI WKH *
WKH VSHFWUXP > @

\$OWKRJK FRQHV DEVRUSWLRQ VSH
SHDNV DEVRUEDQFH ZDYHOHQJWK LV Z
D GLIIHUHQFH DURXQG QP > @ 7KLV
WKH SKRWRQ FDWFK UDWI RU HDFK W\
FRORU GLVFULPLQDWLRQ WKLV GLIIH
FULWLFDO IRU WKH EDVLV RI FRORU GL
GLIIHUHQFH EHWZHHQ WKH SHDN VSHFV
ODUJHU FKDQJH LQ ZDYHOHQJWK LV U
GLIIHUHQFH LQ SKRWRQ FDWFK UDW
GLVFULPLQDWLRQ HILFLHQF\ > @)
ZLWK SURWDQRPDO\ KDYH ORVW DOO / J
WR PDNH OLPLWHG UHG JUHHQ GLIIHU
WKH\ PXVW UHWDLQ DW OHDVW WZR G
H[SUHVVHV GLIIHUHQW HQFRGLQJ SLJ
DPLQR DFLG UHVLGXDO ZKLFK GLIIHU
SHDN DQG SURYLGHV WKH EDVLFV IRU V
GLIIHUHQWLDWLRQ > @

:KHQ WKHUH LV RQO\ RQH 0 JHQH UHP
PRUH VHYHUH LQ WKH IRUP RI SURWDQR
FDQQRW PDNH FRORU GLVFULPLQDWL
VSHFWUXP > @ \$OWKRJK LW LV SRV
KDV PXOWLSOH 0 JHQHV LW LV SURSH
SLJPHQWV KDYH LGHQWLFDO VSHFWUD
; FKURPRVRPH SLJPHQW JHQH FRGH IR
DFLG OHDGLQJ WR GLFKURPDWH >
QXFOHRWLGH VHTXHQFH RI ; OLQNH
SURWDQRSPDO\ KDV PRUH WKDQ RQH
VSHFWUDO SLJPHQWV ZKHUHV LQ SU
VHTXHQFH RI FRGRQ > @ +RZHYHU 3L
DOZD\ VKRZ GLIIHUHQFH LQ JHQHV W
DFLGV NQRZQ WR VKLIW WKH PD[DEVR
RQLI WKH SLJPHQWV GRHVQ\W GLIIHU
KRZ GRHV WKH SLJPHQWV GLIIHU WR SU
JUHHQ GLIIHUHQWLDWLRQ LQ SURWDQ
VSHFWULFDQ VHQVLWLYLW\ LQ SURWD
VXEMHFWV FDQ KDYH VOLJKWO\ EURDG
LPSOLHV D FKDQJH LQ HIIHFWLYH RSW
SLJPHQWV DQG DOWHUDWLRQ LQ WKH V
WKH PROHFHOHV 7KHUHIRUH FRQH GH
IRU FRORU YLVLRQ > @

\$FKURPDWRSVLD LV D PRQRFKURPDF
LQYROYHV WKH ORVV RI DOO WCUHH FF
DQG VWXG\ VKRZV WKDW VHYHUDO JHQ
WKLW FRQGLWLRQ 231 /: 231 0: \$7)
&1*% *1\$7 3'(+ DQG 3'(& > @ \$OW
RI WKH PDOIXQFWLRQLQJ JHQRPW WKUR
EH XVHG VXFK DV VLOHQFLQJ PXDWWH
KDUPIXO JHQH E\ UHSODFLQJ LW ZLWK

> @ &1*\$ JHQH LV WKH PRVW F
DFKURPDWRSVLD DV &1*\$ NQRF
VKRZHG FRQH GHDWK DQG VXEVI
> @ 6HYHUDO VWXGLHV WHVW
&1*\$ LQ DQLPDO DQG KXPQV WF
UHVXOWV VKRZHG DQ LPSURYHPI
WKURXJK (5* > @ 7KH UHVXOV
WDUJHWLQJ RWKHU JHQHV LQGL
SURPLVLQJ PHWKRQ LQ WUHDWL
> @ +RZHYHU VXFK PHWKRQ LV
DUHQRW ZLOGO\ XVHG RQ KXPQV
1HXURORJLFDQO\ FRORU YLVL
FRQHV ZLWK GLIIHUHQW SHDN VH
D GLIIHUHQW UDWH &&9' LV GXH
FRQHV DUH DIIHFWHG *HQH
PDOIXQFWLRQLQJ JHQHV EH SUR
IXQFWLRQDOLW\ DQG WUHDWLQ
PHWKRQV DUH VWLOO LQ WHVWLQ
RQ KXPQV

&RJQLWLRQ

7KH &,(FKURPDWLFLW\ GLDJUDP
RQ ;< FRRUGLQDWH ILJXUH >
WKH FRORU ZLWK FRUHVSRQGLQ
UHG RQ WKH ERWRP OHIW DW
ZDYHOHQJWK HQG RI WKH YLVLE
RQ WRS DW QP DQG YLROHW I
ZKLFK LV WKH VKRUW ZDYHOHQ
VSHFWXP > @ ZKLWH LV UR)
GLDJUDP DW WKH 1 SRLQV
FORVHU WR WKLV SRLQW WKH OI
ILJXUH > @

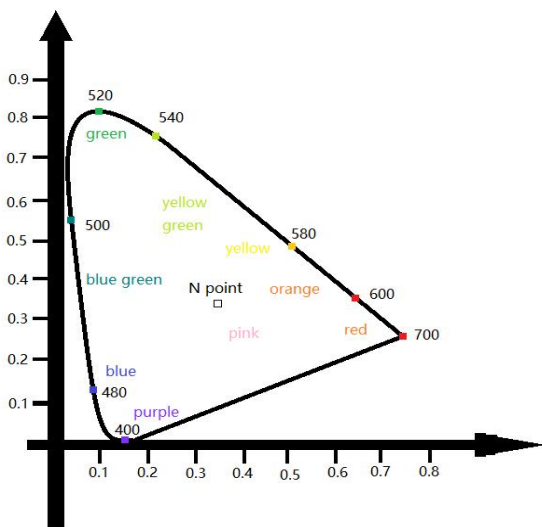


Fig 1: &,(FKURPDWLFLW\ GLDJUDP

:KHQ FRQQHFWLQJ WZR SRLQV
SRVVLELOLWLHV RI WKH PL[WXUH
OLQH VHH ILJXUH ,Q SURWDC
SLJPHQV D PL[WXUH RIEOXH OI
QP ZLOO EH SHUFHLYHG WKH
VLQFH QP OLJKW ZLOO QRW DI

7KH OLQH FRQQHFWLQJ QP WR Q
FKURPDWLFLWLHV WKDQ DQRUPDO SHU
D SURWDQRSH FDQQRW WKLV LV RQH R
OLQHV DQG DQ\ WZR SRLQW RQ WKH F
SHUFHLYHG WKH VDPH IRU SURWDQRSH

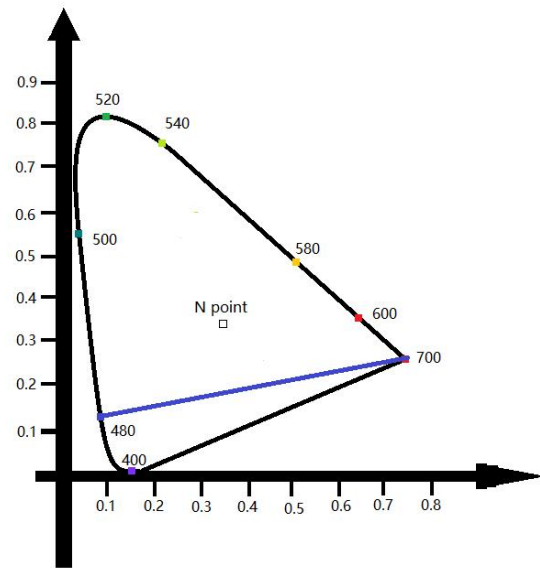


Fig 2 SURWDQRSH FRQIXVLRQ OLQH > @

-RKQ 'DOWRQ D UHG JUHHQ FRORU
UHSRUWV D SLQN IORZHU DV DVN\ EOXH
RQ ZKHWKHU GR UHG JUHHQ GLFKURPD
WKLQJV RU WKH\ VXIIHU IURP FRORU LQ
WR WKH UHGXFWRQ YLHZ WKH UDQJH
FDOOHG JDPXW 3URWDQRSH\ JDPX
\HOORZ EOXH SODQH DQG ZKLWH EODF
OLQH LQ ILJXUH WKLV GRHV QRW WH
VWLPXOXV ORRNV WR D SURWDQRSH >
SURWDQRSH\ JDPXW ZKLFK FRQVLV
QP DQG\HOORZ QP DQG FRQQH
FHQWHU SRLQW DQ\ FRORU OLHV LQ
SHUFHLYHG QRUPDO\ LQ SURWDQRSH
7DNH WKH FRQIXVLRQ OLQH SDVVLQJ
H[DPSOH WKH LQWHUVHFWRQ SRLQW
QRUPDO WULFKRPDWV DV LW GRHV WR
RWKHU SRLQWV RQ WKDW FRQIXVLRQ
SURWDQRSH VHH ILJXUH > @

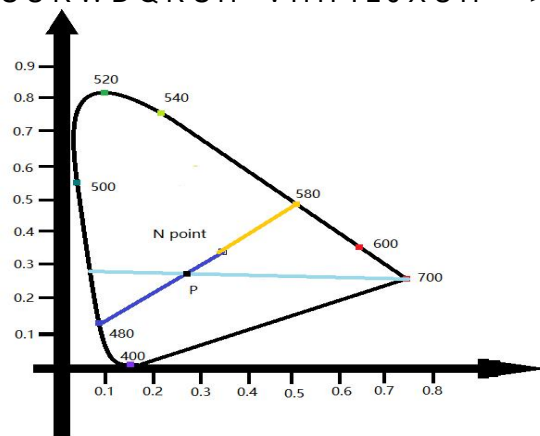


Fig 3: LQWHUVHFWRQ SRLQW 3 ZLOO EH S
WULFKURPDWV LQ SURWDQRSHV > @

+RZHYHU WKHUH DUH GLIILFXC
 YLHZ \$FFRUGLQJ WR WKH UHGX
 DURXQG WKH QHXWUDO SRLQW RI
 ZKLWH E\ SURWDQRSHV WKH OL
 EOXH LVK JUHHQ EHFDXVH SURW
 ORRNVDUN LQ WKHLU H\HV DQG
 > @ 6LPLODUO\ RUDQJH ZRXOG
 LQ GRUPDO WULFKURPDWV VLQ
 \HOORZ EOXH FKDQQHO WRZDUG
 \HOORZ EOXH FKDQQHO LV LQW
 SHUFHLYHG QRUPDOO\ LQ SURW
 UHGXFWRQ YLHZ LW ZLOO EH SI
 DOWHUQDWLYH UHGXFWRQ YLH
 FKDQQHO VXSSOLHV \HOORZLVK
 \HOORZQHVV DQG EOXHQHVV LQ
 FKDQQHO LV ELDVHG WRZDUGV \I
 QRW VLJQDO WKDW WKH VWLWXO
 WKH 6WDQGDUG 5HGXFWRQ 9LH
 DV HLWKHU XQLTXH \HOORZ RU
 DOWHUQDWLYH 5HGXFWRQ 9LHZ
 HLWKHU \HOORZLVK RU EOXLVK
 DOWHUQDWLYH UHGXFWRQ YLH
 KXH PLVSHUFLSWLRQ DV RUDQ
 DQG QRW \HOORZ 7KXV SURWDQ
 > @

1RUPDO FRORU REVHUYHUV FDC
 FRORUV ZKHUH DV LQ GLFKURPD
 WR RQO\ WKRXVDQG > @ 6
 PHFKDQLVPV PLJKW KHOS WR
 GHILFLHQF\ &9' VXFK DV FRORU
 JODVVHV RU FRPSXWHU DOJR
 VWLWXODWH FRORU YLVLRQ GHIL
 YLVLRQ GRUPDO &91 LQGLYLGX
 GLVFULPLQDWLRQ ZKHQ ZRUQ
 FRPSHQVDWLRQ WRRO > @ 1RW
 KRZ OLJKW IURP GLIIHUHQW SDU
 H\H GHSHQGLQJ RQ WKH ZDYH OH
 VWLWXODWH GLIIHUHQW W\SHV R
 WR VWLWXODWH SURWDQRSH D
 VWLWXODWH /FRQHV LQ &91 REVH
 KDYH OLWWOH RU QRWKLQJ WI
 FRPSHQVDWLQJ IRU &9' QRWFK
 FRQH VSHFWUDO SHDN WR LQFL
 SURYLGHV D PRUH GLVWLQJXLV
 UHFHSWRUV > @ 1RWFK ILOWHU
 SRWHQWLDQO\ JLYLQJ QHZ GL
 WULFKURPDWV DQG GLFURPDWV >

+RZHYHU VXFK SRWHQWLDQ GI
 HIIHFW 9DLUDQRU VWLWXODW
 VWLWXODWH &9' LQ &91 DQG
 FRPSHQVDWLRQ ILOWHU FODLPV
 7KH HILFLHQF\ RI WKHVH ILOW
 VHHUDO FRORU YLVLRQ WHVW
 GHILFLHQF\ 7KH)DUQVZRUWK
 &9\$ 80LQKR \$OWKRXJK YDULDQ
 VXFFHVVIXO LQ PLPLFNLQJ &9'
 (Q&KURPD &; FRPSHQVDWLRQ
 VLJQLILFDQWO\ LPSURYH &9' S
 GLVFULPLQDWH FRORUV LQ FRC
 ZHDNQHVV RI WKLW UHVXOW LV W
 ZKHWKHU ORQJ WHUP XVDJH FDC

WKH ZHDU WKHUHIRUH VXFK UHVXOW
 WHUP XVDJH > @
 \$QRWKHU ZD\ WR LPSURYH FRORU YL
 WKURXJK 'SULQWHG JODVVHV FRQ
 VSHFLDOLJHG WUDQVSDUHQW UHVLQV
 WKDW DOWHU FRQH VSHFWUDO VHQVLRQ
 FRORU YLVLRQ DXJPHQWDWLRQ E\ DE
 ZDYH OHQJWK IRU EOXH \HOORZ
 QP GLFKURPDWV WKXV LPSUR
 GLIIHUHQWLDWLRQ DELOLW\ > @ %\
 &9' SDUWLFLSDQW VKRZHGLJQLILFD
 FRUHFWO\ UHDGLQJ SODWHV LQ ,VKL
 PHWKRGLV HIIHFWLYH LQ DXJPHQW
 GHILFLHQF\ > @ 6LPLODUO\ 'SULQW
 VKRZHGLQDORJR XV UHVXOWV > @ +R
 PHWKRGLV VXFK DV 7KH)DUQVZRUWK
 7HVW DQG &9\$ 80LQKR DUH QRW XVH
 JODVVHV HIIHFWLYHQHV RQ PRQRFKU
 UHPDLQ XQNQRZQ

&RJQLWLYHO\ &,(GLDJUDPV FDQ EH
 WKH JDPXW RI &9' LQGLYLGXDOV YLD F
 WKURXJK WKH UHGXFWRQ YLHZ > @
 XVHG WR VWLWXODWH &9' LQ &91 LQGL
 JRRG FRPSHQVDWLRQ IRU &9' LQGLYL
 DV WKLW H[SHULPHQW RQO\ PHDVXUHV
 WHUP VWXG\ RQ QRWFK ILOWHU HIIHFW
 'SULQWHG JODVVHV DQG FRQWDFW O
 UHVLQV DUH VKRZQ WR EH HIIHFWLYH
 YLVLRQ GLIIHUHQWLDWLRQ > @ +RZH
 LV XVHG DV PHDVXUHV DQG HI
 PRQRFKURPDF\ \$FKURPDWRSVLD UHTX

'LVFXVVLRQ

&RQJHQLWDO FRORU YLVLRQ GHILFLH
 OLQNHG GLVHDVH GXH RQH RU PRUH W
 DIIHFWHG V\PSWRPV LQFOXGH UHGX
 FRPSOHWH ORVW RI FRORU YLVLRQ GLI
 DQRPDO\ LV GXH WR ORVW RI FRQHV DQ
 VSHFWUDO SHDN LV WRR VPDOO WR GL
 WKH VSHFWUXP > @ 1HXURORJLFDOO
 UHVSQRVLEOH IRU &&9' IRU H[DPSO
 UHVSQRVLEOH IRU \$FKURPDWRSVLD >
 WKHUDS\ WDUJHWLQJ &1*\$ VKRZHGL
 WUHDWLQJ &&9' KRZHYHU VXFK PHWK
 XVHG DV D OHJLW WKHUDS\ > @

&RJQLWLYH PHWKRGLV VXFK DV QRWFK
 FRPSHQVDWLRQ \HW VXFK PHWKRGLV V
 OHDVW LQ WKH VKRUW WHUP > @ *OD
 XQGHVLUHG ZDYH OHQJWK VKRZHGL
 FRORU YLVLRQ GLVFULPLQDWLRQ > @
 RQO\ VKRZHGLPSURYHHPHQW LQ ,VKL
 WHVWLQJ PHWKRGLV VXFK DV 7KH)DUQ
 +XH 7HVW DQG &9\$ 80LQKR QHHG IXUWH
 'HVSLWH FXUH RQ &&9' UHPDLQLQJ LQ
 QHXURORJLFDOO\ DQG FRJQLWLYHO\
 VKRZHGLSURPLVLQJ UHVXOWV LQ URGH
 KXPQV 7KHUHIRUH IXWXUH VWXG\
 QHXURORJLFDO DVSHFW ZRXOG SRVVL
 FXULQJ &&9'

&RQFOXVLRQ

, Q D QHXURORJLFDQ VWDQGSRLQ
 LV FULWLFDO LQ &RORU GLVFULP
 FRQHV ZLOO FDXVH WKLV GLIIHU
 UHGXFHG FRORU GLIIHUHQWLD
 VWDQGSRLQW &,(GLDJUDPV FDC
 VSHFWUDO JDPXW RI &'9 SDWLHQ
 VWDWHV WKDW WKH &'9' LQGLY
 DIIHFWHG FRORUV ZLWK ELDV WR
 H[DPSOH SURWDQRSH YLVLRQ ZL
 DQG EOXH VLQFH WKHLU\HOORZ
 &XUUHQWO\ DOO WKHUDS\ PHW
 OLPLWDWLRQV JHQH WKHUDS\ V
 ZDV QRW XVHG ZLGHO\ DV WKHUD
 RQO\ PHDVXUHG WKURXJK ,VKLKD
 PHDVXUHPHQW UHVXOW DQG LW
 UHPDLQ XQNQRZQ 'HVSLWH WKH
 VKRZHG SURPLVLQJ UHVXOW LQ U
 DQG VKRXOG FRQWLQXH LQ WKLV
 FRPSHQVDWLRQ JODVVHV LQGH
 UHFYHU\ LQ GLFKURPDWLF SDWI
 ,VKLKDUD SODWHV 3DWHQWV ZL
 FRPSHQVDWLRQ JODVVHV WR HQ
 SHUFHSWLRQV)XWXUH VWXGLH\
 JHQH WKHUDS\ DQG FRORU YLVLR
 SURYLGH D QRUPDO YLVLRQ WR &!

- &RKHQ 0 0DWWKHQ &RORU RQW
 VFLHQFH &DPEULGJH 0\$ 0,7 SUHV

5HIHUUHQFHV

) \$ODP 6DOLK 0 (OVKHULI :
 %XWW \$GY (QJ 0DWHU
) \$ODP \$(6DOLK 0 (OVKHU
 %XWW \$GGLW 0DQXI
 / ÈOYDUR - 0 0 /LQKDUH 0
 6 - :DXJK 6FL5HS 8N
 \$ 6WRFNPDQ &XUU 2SLQ %HKI
 - %RVWHQ &XUU 2SLQ %HKDY
 0 6 \$NKWDU 0 \$VODPNKDQ
 \$ 5 +DULV ,QW -)URQ 6FL
 % 6ZDWKL 5 .RXVKDO\ D - 9
 *RZWKDP ,5-(7
 0 3 6LPXQRYLF 6XUY 2SKWK

 % 5 0LJHRQ *HQHW 0HG
 % 5 0LJHRQ *HQGHU 0HG
 5 * 0LWLNX % 6 7ROHUD =
 3XEOLF+HDO
 0)DUHHG 0 \$ \$QZDU 0 \$IJD

 . 3 0DVKLJH ' % 9 6WDGHQ

 = (0RXVVDZL 0 %RXHLUL
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 - 1HLW] 0 1HLW] - & +H 6
 1HXURVFL