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ABSTRACT
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associations that is analyzed. This paper uses an actual data set (N=539;
variables =98) to illustrate that these two methods converge in their results
when the number of variables is large, even if score reliabilities are low.
(Contains 2 tables and 13 references.) (Author/SLD)

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Principal Components versus Principle Axis Factors:

When Will We Ever Learn?

Bruce Thompson                    Sherry A. Vidal-Brown

Texas A&M University              University of Houston
            and
Baylor College of Medicine

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## Abstract

Analysts differ quite heatedly over the use of principal components as against principle axis factor analysis. The present paper uses an actual data set ($\underline{n}$ = 539; variables = 98) to illustrate that these two methods converge in their results when the number of variables is large, even if score reliabilities are low.

As Thompson and Daniel (1996) noted,

> Analysts differ quite heatedly over the utility of principal components as compared to common or principle [axis] factor analysis [i.e., PAF].... The differences between the two approaches involves the entries used on the diagonal of the matrix of associations that is analyzed. When a correlation matrix is analyzed, principal components analysis uses ones on the diagonal whereas common factor analysis uses estimates of reliability, usually estimated through an iterative process. (p. 201)

These differences are so heated that an entire special issue (Mulaik, 1992) on this controversy was published in *Multivariate Behavioral Research*.

Thompson (1992) argued that the practical difference between the methods is often negligible in terms of interpretation. Differences in results will decrease as (a) the measured variables have greater score reliability or (b) the number of variables measured increases (Gorsuch, 1986).

Regarding the first influence, the higher the score reliability is for a variable, the closer the PAF entry on the diagonal is to one, which is what is used by PCA. So in cases where the reliability of variable scores is high, PCA AND PAF will converge in their estimates. Of course, understanding this influence requires understanding of basic concepts of reliability; useful treatments of these concepts are provided by Dawson (1999),

Reinhardt (1996), Thompson and Vacha-Haase (2000), and Vacha-Haase, Kogan and Thompson (2000).

Regarding the second influence, as the number of variables increases, so does the total number of entries on the matrix of associations. The influence of the diagonal entries then has less influence on the solution, because the proportion of entries on the diagonal decreases exponentially as more variables are measured (cf. Snook & Gorsuch, 1989). For examples, with 10 measured variables there are 10 diagonal entries out of 100 total entries (i.e., 10.0%), but with 30 measured variables there are 30 diagonal entries out of 900 total entries (i.e., 3.3%), and with 50 measured variables there are 50 diagonal entries out of 2500 total entries (i.e., 2.0%). So even when the scores on the variables are not very reliable, PCA and PAF will still tend to converge if the number of variables is large.

The present paper provides a heuristic exploration of these influences. Data from 539 college students on the *Career Assessment Diagnostic Inventory* (CADI) were the basis for the comparison. The CADI is a 98-item multidimensional measure of career-indecision factors (Vidal-Brown & Thompson, in press).

The data provide a useful comparison of PCA versus PAF results, because the rank of the matrix is large. In this case, the diagonal represents roughly 1% of the entries in the correlation matrix (i.e., 98 / [96 x 98] = 98 / 9604 = 1.02%).

### Results

Table 1 presents the varimax-rotated pattern/structure

coefficients from a *principal components* analysis of the data. Table 2 presents the varimax-rotated pattern/structure coefficients from a *principle axis factor analysis* of the data.

INSERT TABLES 1 AND 2 ABOUT HERE

## Summary

The present results illustrate a dynamic that we as a field seem to continue to relearn: PCA and PAF structures tend to be comparable when the number of factored entities is large. This true regardless of whether we are factoring variables, people, or time (Thompson, 2000). Of course, we rarely apply factor analytic methods unless there are a fair number of variables (or people, when we factor people), because the structure of few variables is usually uninteresting. In these cases results across the two methods would generally be *expected* to converge. Research analytic practice as regards factor analysis would improve if more researchers understood these and related dynamics (Henson & Roberts, in press).

The order of the present factors does differ somewhat across the analyses (i.e., factors II and III are transposed in their orders). However, in general the order in which a factor is extracted across methods or samples is usually not of any particular interest, unless there is a theory present that predicts a particular factor order. This is not the usual case.

A comparison of the factors reported in Tables 1 and 2 shows that the magnitudes of the absolute values of the pattern/structure

coefficients across the two analyses are slightly smaller for the principle axis factor results. This pattern is typical. However, the critical thing to note is that, notwithstanding this dynamic, *the interpretations of the factors across the two analyses would be comparable*. That is were the rubber meets the road in the factor analysis endeavor!

These results illustrate that principal components is a perfectly reasonable analytic choice in many research situations. And there is a unique feature of principal components that may make this choice particularly appealing. In many cases researchers use the pattern coefficients to compute factor scores, which are then used in subsequent analyses (e.g., MANOVA, descriptive discriminant analysis). The correlations of the factors with each other will only exactly match the correlations of the factor scores with each other in a principal components analysis (Wells, 1999).

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Table 1
Varimax-rotated Principal Components
Pattern/Structure Coefficients

| | | | Component | | | |
|------|--------|--------|---------|---------|---------|---------|
| Item | I | II | III | IV | V | VI |
| Q7 | .07887 | .08909 | .02415 | .63562 | .03689 | .09586 |
| Q13 | .13709 | .05133 | .06022 | .69143 | -.18760 | .00782 |
| Q19 | .13815 | .01652 | .05506 | .66465 | .05833 | -.15052 |
| Q25 | .12154 | .05949 | .03007 | .66873 | .20616 | -.11626 |
| Q37 | .31287 | .14320 | .06437 | .46758 | .10381 | -.09002 |
| Q43 | .11905 | .01245 | .07926 | .77720 | .02738 | -.05259 |
| Q49 | .15164 | .04622 | .02527 | .68634 | -.00668 | -.02000 |
| Q55 | .12632 | .01154 | .00141 | .62046 | .00935 | -.15481 |
| Q61 | .09232 | .09182 | .02725 | .70489 | -.03675 | .02068 |
| Q67 | .05714 | .22961 | -.00655 | .61141 | .02291 | -.15518 |
| Q73 | .02064 | .00687 | -.01387 | .51325 | .04453 | -.12692 |
| Q79 | .10110 | .04632 | .02687 | .64377 | -.03163⁻ | .01930 |
| Q85 | .09887 | .12241 | -.00223 | .66185 | .02455 | -.06492 |
| Q31 | -.16366 | -.05643 | -.04305 | -.61090 | .13596 | .12373 |
| | | | | | | |
| Q23 | -.12359 | -.08476 | -.03227 | -.12605 | .42527 | .06964 |
| Q29 | -.02426 | .04688 | .13122 | .18306 | .31617 | .08176 |
| Q35 | .06790 | .11468 | .04622 | -.04877 | .59533 | -.01653 |
| Q41 | .20313 | .13231 | .13851 | .16007 | .42829 | .01519 |
| Q47 | .07428 | .02833 | -.01084 | -.17398 | .61032 | -.08667 |
| Q71 | .11512 | .08913 | .03513 | .13555 | .67717 | .03701 |
| Q83 | .07542 | .05171 | .03442 | .05129 | .72948 | .00241 |
| Q88 | .07373 | .17803 | .07899 | .32821 | .58570 | -.16080 |
| Q91 | .25491 | .39270 | .31058 | .16107 | .39127 | .06281 |
| Q94 | -.16583 | -.11050 | -.02469 | -.17395 | .58422 | .13671 |
| Q96 | .34568 | .28542 | .08962 | .20987 | .27124 | -.02696 |
| Q98 | -.09791 | -.01806 | -.05575 | -.28087 | .44611 | .01340 |
| Q100 | .12876 | .06726 | .07499 | .09948 | .70104 | .04682 |
| Q102 | .08636 | .18442 | .07209 | .14082 | .71180 | .02109 |
| Q104 | .14362 | -.02389 | .07302 | .07097 | .46348 | -.07328 |
| Q59 | .18021 | -.13390 | -.13203 | .15810 | -.46148 | -.02732 |
| Q65 | -.05622 | -.11287 | -.06921 | .05008 | -.45110 | -.00918 |
| Q77 | .03998 | -.11052 | .01541 | -.12877 | -.56432 | .12491 |
| | | | | | | |
| Q2 | .16258 | .71759 | .21406 | .08713 | -.03753 | -.07993 |
| Q8 | .10437 | .63515 | .17359 | .12309 | .08483 | -.09590 |
| Q14 | .20330 | .73498 | .27911 | .10062 | .00312 | -.06818 |
| Q20 | .19366 | .65359 | .11139 | .18735 | .05922 | -.05972 |
| Q26 | .16520 | .76457 | .22325 | .06582 | .11998 | -.03925 |
| Q32 | .05863 | .53531 | .26602 | .06769 | .10418 | -.04541 |
| Q38 | .20485 | .75350 | .21392 | .12144 | .05996 | -.03402 |
| Q62 | -.21427 | -.63565 | -.20654 | .12264 | -.10739 | .08417 |
| Q68 | .14502 | .68034 | .14467 | .09192 | .10500 | .01250 |
| Q74 | .22322 | .69382 | .24065 | .12092 | .16671 | -.01681 |
| Q80 | .19517 | .68807 | .27268 | .09175 | .14788 | -.02113 |
| Q44 | -.11976 | -.66466 | -.21615 | -.01648 | -.04788 | .06915 |
| Q50 | -.24263 | -.62987 | -.07986 | -.07596 | -.07752 | .11871 |
| Q56 | -.18530 | -.42099 | -.07515 | -.08407 | -.05264 | .12054 |

| | | | | | | |
|------|---------|---------|---------|---------|---------|---------|
| Q3   | -.37458 | -.19583 | -.00128 | .00111  | .01416  | .21197  |
| Q15  | -.37827 | -.02638 | -.00874 | -.10512 | .07276  | .33999  |
| Q21  | -.34485 | -.06234 | .08184  | -.10390 | .13425  | .07082  |
| Q51  | -.70695 | -.31158 | -.01451 | -.05433 | -.07339 | .19774  |
| Q63  | -.78892 | -.15129 | -.04918 | -.12471 | -.01822 | .10817  |
| Q75  | -.49991 | -.02421 | -.06213 | -.09568 | .07702  | .30147  |
| Q81  | -.58063 | -.18766 | -.06861 | .00249  | -.00205 | .20502  |
| Q86  | -.64424 | -.13955 | -.00829 | -.03081 | .01063  | .20533  |
| Q93  | -.78513 | -.13681 | .01834  | -.11178 | -.00457 | .13481  |
| Q9   | .67052  | .06061  | .09766  | .13032  | .08277  | .05971  |
| Q27  | .48499  | .42325  | .06917  | .02868  | .06269  | -.14705 |
| Q33  | .66473  | .15442  | .02373  | .19845  | .17029  | .04819  |
| Q39  | .71133  | .24486  | .06505  | .19146  | .13065  | .04121  |
| Q45  | .50845  | .05355  | .00368  | .22055  | .03098  | -.03486 |
| Q57  | .56530  | .35004  | .14475  | .15697  | .13159  | .06302  |
| Q69  | .64902  | .02925  | .07369  | .23526  | .03738  | .06331  |
| Q90  | .76793  | .10399  | .02870  | .16176  | .14729  | .04840  |
|      |         |         |         |         |         |         |
| Q4   | .01363  | .17042  | .60103  | .02590  | .02316  | -.00709 |
| Q10  | .08891  | .08048  | .62856  | .07856  | .03634  | -.02401 |
| Q16  | -.00089 | .30492  | .63468  | -.02867 | .04502  | .05667  |
| Q22  | -.10889 | .32931  | .61085  | -.04845 | -.01929 | .04628  |
| Q28  | .00413  | .31917  | .75062  | .03761  | .01876  | -.01684 |
| Q34  | .06487  | .24460  | .74003  | -.07850 | .01221  | .06568  |
| Q40  | .09283  | .18288  | .65828  | .07794  | .14210  | .06732  |
| Q46  | .10428  | .13111  | .68149  | .06496  | .12987  | .05774  |
| Q52  | .01864  | .17668  | .79109  | -.03360 | .03238  | .04587  |
| Q58  | .02962  | .14636  | .69580  | -.01450 | .06571  | .17757  |
| Q64  | -.02006 | .11347  | .77219  | .02429  | -.01348 | .09786  |
| Q70  | .06841  | .12343  | .74810  | .03331  | .03470  | .04910  |
| Q76  | .00705  | -.03394 | .42956  | .12686  | .01826  | -.00331 |
| Q82  | .01208  | .15019  | .72204  | -.00513 | .07545  | .18873  |
| Q87  | -.00308 | .11333  | .71667  | .08174  | .12803  | .13011  |
|      |         |         |         |         |         |         |
| Q6   | -.15080 | -.29411 | -.01276 | -.01837 | -.10065 | .37794  |
| Q12  | -.46585 | -.13156 | -.04108 | -.04227 | -.08925 | .24124  |
| Q18  | -.02507 | -.01265 | .18930  | -.11374 | .02260  | .47291  |
| Q24  | -.46604 | -.20972 | .06493  | -.06876 | -.02317 | .27548  |
| Q36  | -.52172 | -.18612 | .00426  | -.01409 | -.02968 | .33211  |
| Q54  | -.00502 | -.16410 | -.03814 | -.11317 | -.19195 | .40274  |
| Q60  | -.21019 | -.16708 | .13741  | -.01575 | -.06066 | .44942  |
| Q66  | -.01463 | .05294  | .04762  | .01877  | .04656  | .43354  |
| Q72  | -.09683 | -.03485 | .01493  | .06452  | -.27855 | .22822  |
| Q78  | -.09544 | -.03832 | .11240  | -.04587 | .09050  | .46189  |
| Q84  | -.24225 | -.15900 | .06605  | -.07460 | -.01736 | .41369  |
| Q89  | -.07209 | -.01149 | -.07664 | -.03908 | -.19586 | .38570  |
| Q92  | -.11925 | .02776  | .03823  | .03295  | .05882  | .69847  |
| Q95  | .02545  | -.02861 | .15481  | -.00063 | .14196  | .45009  |
| Q97  | -.10568 | .13544  | .23895  | -.01313 | .07665  | .57784  |
| Q103 | -.14473 | .06840  | .09970  | -.02034 | .07105  | .66549  |
| Q30  | -.04398 | .16343  | .04448  | .12996  | -.04396 | -.36631 |
| Q42  | .16780  | .20023  | .02952  | .27071  | .09884  | -.37374 |
| Q48  | .13637  | .16308  | .06278  | .27860  | .17656  | -.39663 |
| Q101 | .12978  | .05741  | .00727  | .17790  | .16808  | -.42126 |

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Table 2
Varimax-rotated Principle Axis Factors
Pattern/Structure Coefficients

| | | | Factor | | | |
|---|---|---|---|---|---|---|
| Item | I | II | III | IV | V | VI |
| Q7 | .08262 | .03388 | .08153 | .60115 | .03685 | .07598 |
| Q13 | .13686 | .06050 | .05086 | .66842 | -.17979 | .00072 |
| Q19 | .13869 | .05224 | .02124 | .63852 | .05701 | -.14690 |
| Q25 | .12270 | .03236 | .05932 | .64583 | .20066 | -.11691 |
| Q37 | .30214 | .06644 | .14264 | .44535 | .10193 | -.09726 |
| Q43 | .11847 | .07934 | .01142 | .76467 | .02699 | -.05433 |
| Q49 | .15149 | .02628 | .04815 | .65839 | -.00517 | -.02441 |
| Q55 | .12990 | -.00058 | .01720 | .58815 | .01045 | -.14665 |
| Q61 | .09612 | .03271 | .08705 | .67750 | -.03386 | .01142 |
| Q67 | .07197 | .00109 | .21756 | .58143 | .02616 | -.14650 |
| Q73 | .03431 | -.01610 | .01381 | .47157 | .04139 | -.11139 |
| Q79 | .10392 | .03080 | .04482 | .60842 | -.02736 | .00815 |
| Q85 | .10644 | .00238 | .11789 | .63047 | .02689 | -.06439 |
| Q31 | -.16107 | -.04431 | -.05577 | -.58314 | .12485 | .12827 |
| | | | | | | |
| Q23 | -.11619 | -.02940 | -.07569 | -.11941 | .37935 | .06986 |
| Q29 | -.01212 | .12720 | .04750 | .16341 | .28389 | .07569 |
| Q35 | .06773 | .05152 | .11204 | -.04287 | .55564 | -.01579 |
| Q41 | .19482 | .13642 | .13359 | .15330 | .39822 | .00762 |
| Q47 | .06909 | -.01119 | .03637 | -.16026 | .57157 | -.07526 |
| Q71 | .11420 | .04218 | .08406 | .13112 | .65221 | .03090 |
| Q83 | .07299 | .03655 | .05199 | .05054 | .70703 | .00200 |
| Q88 | .08028 | .08290 | .17085 | .31753 | .56784 | -.15303 |
| Q91 | .25423 | .31127 | .37738 | .16019 | .38291 | .05632 |
| Q94 | -.16105 | -.02266 | -.10323 | -.16874 | .54555 | .13410 |
| Q96 | .33219 | .09841 | .27228 | .20525 | .26033 | -.04065 |
| Q98 | -.09327 | -.05157 | -.01469 | -.26016 | .40482 | .02231 |
| Q100 | .12500 | .07753 | .06595 | .09695 | .67916 | .04215 |
| Q102 | .08818 | .07845 | .17496 | .13787 | .69850 | .01903 |
| Q104 | .13295 | .06186 | -.00173 | .07058 | .42068 | -.06084 |
| Q59 | .15851 | -.13389 | -.11864 | .14842 | -.42667 | -.03562 |
| Q65 | -.05876 | -.07563 | -.10446 | .04299 | -.41116 | -.00697 |
| Q77 | .02344 | .00504 | -.10130 | -.12054 | -.52555 | .11100 |
| | | | | | | |
| Q2 | .17034 | .22682 | .69145 | .08998 | -.02697 | -.08525 |
| Q8 | .11711 | .19263 | .59258 | .12380 | .09348 | -.10371 |
| Q14 | .20843 | .28916 | .71917 | .10322 | .00943 | -.07289 |
| Q20 | .20243 | .12869 | .62051 | .18598 | .06676 | -.06640 |
| Q26 | .17058 | .23444 | .74962 | .06857 | .12561 | -.04322 |
| Q32 | .07300 | .27216 | .49816 | .06930 | .10898 | -.04584 |
| Q38 | .21139 | .22490 | .73769 | .12336 | .06545 | -.03724 |
| Q62 | -.21851 | -.22226 | -.60070 | .11090 | -.11343 | .09300 |
| Q68 | .15758 | .16355 | .64252 | .09301 | .11130 | .00492 |
| Q74 | .22959 | .25228 | .67199 | .12268 | .17203 | -.02204 |
| Q80 | .20298 | .28245 | .66545 | .09381 | .15345 | -.02392 |
| Q44 | -.13149 | -.23301 | -.62370 | -.02211 | -.05809 | .07616 |
| Q50 | -.24944 | -.10131 | -.59135 | -.07943 | -.08404 | .12647 |
| Q56 | -.18876 | -.09353 | -.37954 | -.08742 | -.06035 | .12487 |

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| | | | | | | |
|------|----------|----------|----------|----------|----------|----------|
| Q3   | -.34496  | -.00838  | -.18687  | -.01512  | .00417   | .21134   |
| Q15  | -.34734  | .00285   | -.04425  | -.11211  | .06174   | .31688   |
| Q21  | -.30879  | .07089   | -.06309  | -.10550  | .11583   | .08813   |
| Q51  | -.69563  | -.02289  | -.30273  | -.05977  | -.07533  | .21308   |
| Q63  | -.77946  | -.05382  | -.14493  | -.12807  | -.01831  | .12361   |
| Q75  | -.46201  | -.04842  | -.04345  | -.10506  | .06592   | .29072   |
| Q81  | -.54851  | -.07108  | -.18431  | -.01233  | -.00926  | .21272   |
| Q86  | -.61204  | -.00962  | -.14286  | -.04245  | .00642   | .21442   |
| Q93  | -.77435  | .01250   | -.13083  | -.11534  | -.00500  | .15094   |
| Q9   | .63769   | .09394   | .06949   | .13442   | .08050   | .04057   |
| Q27  | .46812   | .08019   | .40403   | .03992   | .06884   | -.15571  |
| Q33  | .64247   | .02701   | .15512   | .19958   | .16629   | .03206   |
| Q39  | .70034   | .06588   | .24258   | .19368   | .13036   | .03319   |
| Q45  | .46918   | .00261   | .06767   | .21709   | .03242   | -.05007  |
| Q57  | .54850   | .15031   | .33901   | .15993   | .13287   | .04529   |
| Q69  | .61905   | .06903   | .03946   | .23377   | .03811   | .04754   |
| Q90  | .75742   | .02915   | .10225   | .16431   | .14570   | .03965   |
|      |          |          |          |          |          |          |
| Q4   | .01659   | .56312   | .17419   | .02857   | .02830⁻  | .00641   |
| Q10  | .08286   | .58602   | .09483   | .07997   | .03951   | -.01180  |
| Q16  | .00615   | .61328   | .29542   | -.02415  | .04995   | .06329   |
| Q22  | -.09513  | .59377   | .31338   | -.04494  | -.01205  | .05274   |
| Q28  | .00741   | .74366   | .30942   | .03958   | .02279   | -.01443  |
| Q34  | .06726   | .72774   | .23550   | -.07419  | .01622   | .06725   |
| Q40  | .09410   | .63138   | .18344   | .07865   | .14025   | .07477   |
| Q46  | .10171   | .65383   | .13357   | .06647   | .12977   | .06233   |
| Q52  | .02046   | .78133   | .16821   | -.03112  | .03552   | .04789   |
| Q58  | .03112   | .67261   | .14385   | -.01189  | .06790   | .17891   |
| Q64  | -.01746  | .75210   | .11187   | .02530   | -.01027  | .10446   |
| Q70  | .06805   | .72526   | .12237   | .03572   | .03821   | .05473   |
| Q76  | .00596   | .37638   | -.00332  | .11718   | .01973   | .01807   |
| Q82  | .01385   | .70521   | .14450   | -.00333  | .07689   | .18706   |
| Q87  | -.00053  | .69161   | .11451   | .08098   | .12816   | .13740   |
|      |          |          |          |          |          |          |
| Q6   | -.15780  | -.01811  | -.27367  | -.02824  | -.09948  | .33952   |
| Q12  | -.43191  | -.03884  | -.13787  | -.05506  | -.08803  | .23670   |
| Q18  | -.03376  | .18474   | -.01500  | -.11024  | .01916   | .42290   |
| Q24  | -.43940  | .05458   | -.20319  | -.07933  | -.02813  | .27336   |
| Q36  | -.49550  | .00170   | -.18452  | -.02750  | -.03467  | .32680   |
| Q54  | -.02695  | -.03391  | -.15525  | -.10999  | -.17830  | .34778   |
| Q60  | -.20677  | .12718   | -.15752  | -.02642  | -.06056  | .41323   |
| Q66  | -.02154  | .06374   | .03675   | .01025   | .04196   | .36496   |
| Q72  | -.09213  | .01554   | -.04103  | .04962   | -.24892  | .19890   |
| Q78  | -.09808  | .11208   | -.03831  | -.05098  | .07884   | .41130   |
| Q84  | -.23657  | .06230   | -.15258  | -.08174  | -.02169  | .37688   |
| Q89  | -.07651  | -.05594  | -.02903  | -.04444  | -.17671  | .32594   |
| Q92  | -.10969  | .04298   | .02161   | .02318   | .05189   | .67488   |
| Q95  | .01100   | .15025   | -.02214  | -.00524  | .12757   | .39711   |
| Q97  | -.09712  | .23955   | .12117   | -.01916  | .07183   | .54291   |
| Q103 | -.13386  | .10375   | .05945   | -.02759  | .06306   | .64010   |
| Q30  | -.01872  | .03307   | .15564   | .12284   | -.03482  | -.30591  |
| Q42  | .17519   | .02389   | .19821   | .25931   | .09584   | -.33092  |
| Q48  | .14556   | .05189   | .16693   | .26691   | .16687   | -.34898  |
| Q101 | .13436   | -.00491  | .06936   | .17190   | .15574   | -.36679  |

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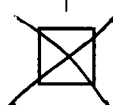| The sample sticker shown below will be affixed to all Level 1 documents | The sample sticker shown below will be affixed to all Level 2A documents | The sample sticker shown below will be affixed to all Level 2B documents |
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